NASA Technical Memorandum 110445

Director's Discretionary Fund Report for Fiscal Year 1996

Ames Research Center

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National Aeronautics and
Space Administration

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CONTENTS

INTRODUCTION

The Director's Discretionary Fund (DDF) at Ames Research Center was established to fund innovative, high-risk projects in basic research that are essential to our future programs but otherwise would be difficult to initiate. Summaries of individual projects within this program are compiled and issued by Ames each year as a NASA Technical Memorandum.

These summaries cover 17 final and 21 ongoing projects in Fiscal Year 1996.

The contents are listed alphabetically according to the last name of the primary investigator in two sections (final and ongoing reports). Following the narrative reports, two appendixes (for final and ongoing reports) contain brief descriptions with the financial distribution and status of each of the projects.

Any questions can be addressed to an investigator directly.

SECTION 1
FINAL REPORTS

Waterproofing the Space Shuttle Tiles

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Other personnel involved
D. Chong, Ames Research Center/Stanford University Summer Faculty Fellows Program

Objectives of the study
To investigate possible surface coatings to make silica waterproof at high temperatures, eliminating the need to rewaterproof the Space Shuttle tiles after each flight.

Progress and results
Results in the first year of this research indicated that a monolayer coating of scandium or zirconium fluoride might permanently waterproof silica. The metal-F bond is very strong because of F lone-pair donation into the empty metal d orbitals. Thus the coating might not be displaced by OH, the typical wetting mechanism. The monolayer coating is also less ionic than bulk metal fluorides, so dissociation of water on the coating is unfavorable. In the second year titanium fluoride was tested, yielding results very similar to those of scandium and zirconium fluoride. These results suggest that any of the early metal fluorides could be tested as a possible coating.

Since confirmation of the early metal fluoride coating is best done by experiment, during the remainder of the second year other aspects of the problem were studied. First, the method used to study the silica surface (denoted B3LYP) was retested. Although the early calibration studies of the B3LYP method showed no problems, some published reports suggested that the accuracy of this approach is variable. The new calibrations included vibrational frequencies of silicon containing compounds and bond energies of transition metal compounds. The new calibration calculations were in very good agreement with experiment and higher levels of theory. Although no experimental data are available for comparison, accurate calculations for the water/silica interaction were performed, and results confirmed the accuracy of the B3LYP approach. Thus there appears to be no reason to question the B3LYP results for the silica system.

The second extension of this work was the study of defect sites. Experimental studies of the surface vibrations were interpreted in terms of two defect sites. The calculations yield frequencies and isotopic shifts in good agreement with the Si3 ring defect model, but not with the Si4 ring model.

Keywords
Silica, Chemisorption

Thermal Protection Systems for Reusable Launch Vehicles

Investigator(s)
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Objectives of the study

New, reusable launch vehicles (RLVs) such as the X-33, which can achieve quicker turnaround and lower cost than the Space Shuttle, are required to render access to space cheaper and more readily available. Current designs are focused on all rocket-powered, vertical-takeoff and horizontal-landing vehicles. The vertical-takeoff designs will minimize heating loads on ascent except at the base of the vehicle, where reverse flow and radiation by the exhaust gases require thermal shielding. However, there will be considerable heating on the nose, wing leading edges, fins, flaps, and the forebody on re-entry at high speeds. These thermal loads will require durable, lightweight, reusable thermal protection systems (TPSs).

In order to study the properties (weight, thickness, catalytic effects) of these TPS designs, a vehicle synthesis code is required. HAVOC (Hypersonic Aircraft Vehicle Optimization Code) is an engineering code that was developed at the Ames Research Center. Although HAVOC was initially used to design air-breathing single stage to orbit (SSTO) vehicles such as the National Aero-Space Plane (NASP), this code has since been modified to study all-rocket RLVs. Performance parameters that can be predicted by HAVOC include the vehicle weight, size, payload, aerodynamic characteristics, and structural design. The TPS requirements are determined by the heating loads on re-entry. An automated vehicle closure algorithm iterates the trajectory analysis to close the design on both vehicle weight and volume.

Until now, no engineering heating analysis code has included variable catalytic effects because of the complexity of the surface catalytic processes, which would be too computationally intensive to include in engineering codes. Many methods of adding the effects of variable catalytic heating enhancement to HAVOC have been examined. Originally, HAVOC used the common assumption that the chemical species, in particular atomic oxygen and nitrogen, are in equilibrium throughout the boundary layer. This assumption is critical since there can be considerable dissociation of the air behind the bow shock of a re-entry vehicle at certain speeds and altitudes. The oxygen and nitrogen atoms are transported from the nose region of the vehicle to the boundary layer edge and then to the vehicle surface, where they can recombine on the wall and release their heat of dissociation. The degree of recombination depends on the wall material (catalycity) and wall temperature. Recombination is a complicated process involving atom adsorption, surface diffusion, and molecular desorption. Modeling this process in detail would be difficult, and the exact surface chemistry mechanisms are not well known. Engineering codes like HAVOC must use simpler, more practical methods since they perform many simultaneous functions such as vehicle synthesis and trajectory optimization.

Progress and results

One method of including variable catalytic effects is to correct the heating rates calculated from chemical equilibrium, or fully catalytic, assumptions. Engineering codes like HAVOC assume that all species will attain chemical equilibrium at the surface, where temperatures are sufficiently low to ensure virtually complete atom recombination and the release of the entire heat of dissociation. In reality, the degree of recombination and the corresponding heat release should be calculated according to the catalytic efficiency of the surface. For example, ceramic materials are much less catalytic than metallic surfaces, no surface has 100-percent catalytic efficiency, and highly catalytic processes usually become diffusion-limited.

The degree of catalyticity is defined by the atom recombination coefficient, which is the fraction of atoms that are available to recombine on the surface that actually recombine. Recombination coefficients are usually written in the form of an Arrhenius expression, which includes the reliance of the surface reaction rates on the wall temperatures and materials. The recombination efficiencies typically range from 0.01 to 0.03 for ceramic and carbon-carbon materials with glass coatings. Metallic materials such as inconel are much more catalytic, with coefficients ranging from 0.3 to 0.6.

Since not all the atoms recombine on the wall, corrections to the equilibrium, or fully recombined, heating calculations are necessary. A method that corrects the heating calculations as they are performed and gives the proper limiting heating values has been developed. HAVOC calculates heat transfer by using the difference between the recovery enthalpy and the

wall enthalpy at any point. The recovery enthalpy is calculated by adding the recovered kinetic energy of the flow to the edge enthalpy, where the edge is assumed to be in chemical equilibrium. At certain speeds and altitudes, there is complete dissociation of oxygen and some dissociation of nitrogen at the equilibrium boundary layer edge. In the equilibrium heating calculations originally performed by HAVOC, the heat of dissociation of these atoms was fully recovered and contributed to the overall heating rate. This situation was equivalent to a perfectly catalytic surface, so adjustments had to be made to the heating rate calculations for partially catalytic surfaces.

This modification was accomplished by knowing the fraction of dissociative energy at the boundary layer edge, which was not recovered. This unrecovered energy was subtracted from the original recovery enthalpy and the modified recovery enthalpy was then used to calculate heat transfer. Note that if the atom recombination coefficients represented the fully catalytic case, no correction was made to the recovery enthalpy. Conversely, if they represented the noncatalytic case, the maximum correction was applied.

The degree of dissociation was calculated at the boundary layer edge by assuming chemical equilibrium using edge conditions that were determined by a shock-expansion method from the stagnation point. Some kinetic evidence, however, indicates that there is not enough time for the atoms to reach equilibrium values as they travel from the nose region. This result indicates that the atoms may be frozen at the higher stagnation point values. Computational fluid dynamics (CFD) results are being checked to see if freezing is predicted for any re-entry cases.

The partially catalytic correction method was tested for ceratin body shapes, TPS materials, and re-entry profiles. One test case was a conical body where the Mangler transformation was added in order to modify the flat-plate heating expressions for conical shapes. The cone was traveling at Mach 14.3 at 100,000 ft with zero angle of attack. Here, the results from BLIMPK, a reacting boundary layer code, were compared to those from HAVOC. Initially, the boundary layer edge conditions were different, with HAVOC showing higher edge velocities and lower edge temperatures than BLIMPK, resulting in different atom concentrations at the edge. In order to upgrade the HAVOC solution methods, the isentropic expansion previously described was added, resulting in similar boundary layer edge conditions for HAVOC and BLIMPK. Fully catalytic and slightly catalytic heating rates also showed good agreement.

These variable catalytic methods are currently being evaluated by comparing HAVOC results to CFD calculations. One question that remains to be answered is whether there are convective or diffusion limits on the transport of atoms to the surfaces. This scenario would have the greatest impact on the fully catalytic assumptions, where transport effects are ignored. Also, a study is needed of the kinetic reactions that occur as the air passes through the shock wave and travels to the boundary layer edge and to the wall. For example, there is a possibility of atoms freezing behind the bow shock, in which case higher than equilibrium atom levels would occur at the boundary layer edges downstream and higher heating rates would result.

Keywords
Reusable launch vehicle, Thermal protection systems, HAVOC

Computer Modeling of the Thermal Conductivity of Cometary Ice

Investigator(s)
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Objectives of the study
To estimate the thermal conductivity of cometary ices from computer simulations of model amorphous ices; work was divided into four specific tasks:

1. To generate samples of amorphous water ices at different microporosities.
2. To compare the resulting molecular structure of the ices with experimental results for those densities for which data are available.
3. To calculate the thermal conductivities of liquid water and bulk amorphous ice and compare these results with experimentally determined thermal conductivities.
4. To investigate how the thermal conductivity of amorphous ice depends upon the microscopic porosity of the samples.

Progress and results
Computer simulations of bulk amorphous ices at the densities of the two major polymorphs, 0.94 g/cc for low-density amorphous (LDA) ice and 1.17 g/cc for the high-density amorphous (HDA) ice have been performed. The structure of the ices, as determined from the pair-correlation functions, was found to be in good agreement with the correlation functions obtained from neutron scattering experiments. Thus the water models that were used in the computer simulations provide a good description of the bulk amorphous ice phases.

Configurations from the bulk simulations were used to generate amorphous substrates. The substrates were equilibrated at 77 and 10 K for the LDA ice and HDA ice, respectively. After equilibration, water molecules were deposited onto the substrated phase from the vapor phase. The temperatures of the vapor phase molecules were 300 K, to simulate laboratory conditions, and 77 K and 10 K, to simulate astrophysical conditions.

Results show that the microporosity of the sample depends upon the temperature of the deposited molecules. The colder the molecules, the more microporous the resulting ice. By depositing water molecules at very low temperatures (10 K) and subsequently heating the resulting microporous ice structure, any desired microporosity can be obtained.

The thermal conductivity, κ, can be calculated from the long-time limit of the heat flux correlation function:

$$\kappa = \frac{1}{2k_B VT^2} \lim_{t\to\infty} \frac{d}{dt} \left\langle \sum_{i,j=1}^{N} E_i(t)E_j(0)\big(x_i(t) - x_i(0)\big)^2 \right\rangle$$

where k_B is the Boltzmann constant, T and V are the temperature and volume of the system, respectively, and $Ei(t)$ and $x_i(t)$ are the energies and positions of molecule i at time t. The double sum is over all N molecules in the system, and <...> denotes a statistical average.

The thermal conductivity of liquid water was determined from the computer simulations at temperatures of 290, 300, and 310 K. These results, as well as experimentally determined values, are shown in table 1. Agreement between the computed and experimental values is good. The difference of a factor of 2 is small compared to the differences between thermal conductivities measured for different laboratory models of amorphous ice. Thus, the computer simulations provide a sufficiently accurate description of the thermal transport properties of water that meaningful conclusions can be drawn from subsequent calculations of the thermal conductivity of the amorphous ice as a function of the degree of its microporosity.

Also shown in table 1 are the computed thermal conductivities of the high- and low-density polymorphs of amorphous ice, HDA and LDA, respectively. They are of the same order of magnitude as the results for liquid water. This result is reasonable because the structure of amorphous ice is quite similar to liquid water. The thermal conductivity of crystalline ice Ih at 100 K is 5.95 $W\text{-}m^{-1}\text{-}K^{-1}$, over an order of magnitude larger than the thermal conductivity of amorphous ice at similar temperatures.

To create samples of microporous amorphous ice, high-temperature simulations at 300 K with fixed bulk densities of 0.9, 0.8, and 0.7 g/cc were performed. Configurations from these calculations were quenched to 77 K to provide a set of initial conditions for calculations of the thermal conductivity. To investigate how different microporous structures might affect the

Table 1. Thermal conductivities of water and amorphous ices

	T (K)	MD κ (W-m^{-1}-K^{-1})	exptl
Water	290	0.19 ± 0.02	0.5917[a]
	300	0.23 ± 0.02	0.6096[a]
	310	0.26 ± 0.01	0.6252[a]
LDA	93	0.15	0.00004b (80–100 K)[b]
HDA	93	0.35	
Microporous[c]			
0.9 g/cc	86	0.12 ± 0.02	
0.8 g/cc	85	0.10 ± 0.02	
0.7 g/cc	86	0.10, 0.23[d] (87 K), 0.14[e] (92 K)	

[a]Ramires, *et al.*, J. Phys. Chem. Ref. Data (1995) **24**, 1377-1381.

[b]Kouchi, *et al.*, Astrophysical J. **388**, L73-L76.

[c]Micropores created by annealing at fixed density from liquid.

[d]Micropores created by random deletion of water molecules followed by quenching.

[e]Micropores created by deletion around a fixed center followed by quenching.

thermal conductivity, two methods for generating such structures were devised. In the first method, water molecules were randomly deleted from a set of LDA ice configurations until the density was 0.7 g/cc. The second procedure was to delete water molecules around a fixed center until a density of 0.7 g/cc was reached. This scenario allows investigations of the possible extremes of the microporous structures: Random deletion of water molecules results in a fairly uniform distribution of small cavities in the structure, whereas deleting water molecules around a fixed center yields much larger cavities.

The computed thermal conductivities of the microporous ices are shown in table 1. The main result is that the thermal conductivity of the microporous ices appear to be of the same order of magnitude as the bulk amorphous ices. The thermal conductivity does not decrease dramatically as the density of the amorphous ice is reduced from 0.94 g/cc to 0.7 g/cc. Since the thermal conductivities for ice samples containing large cavities and uniformly distributed small cavities differ by only a factor of 2, it can be concluded that this quantity is not very sensitive to the distribution of the micropores. Therefore, the microporosity of the ice does not explain the extremely low value of thermal conductivity that has been reported for vapor deposited amorphous ice.

Significance of the results

Since all hypotheses about the role of comets in the origin of life and chemical evolution of the solar system make explicit or implicit assumptions about the thermal conductivity of the cometary ice, the results of these calculations will provide crucial information for the critical evaluation of these hypotheses. Recent experiments on laboratory analogs of cometary ice have yielded values of the thermal conductivity that are several orders of magnitude lower than the thermal conductivity of bulk amorphous ices. This finding has the implication that the interiors of comets are not heated at the perihelion of their orbits.

Whereas the laboratory analogs of cometary ice are prepared by slowly depositing water vapor onto a cold substrate, the bulk amorphous ices are prepared by applying extreme pressure to crystalline ice samples until the underlying lattice is disrupted. It was originally thought that the low measured value of the thermal conductivity might be due to the microscopic porosity of the ice sample. Present results indicate that the thermal conductivities of microporous amorphous ice samples are similar to those of bulk amorphous ice. Consequently, it is likely that the thermal conductivity of astrophysical ice is of the same order of magnitude as normal ice. It is possible that the extremely low thermal conductivity measured in the vapor deposition experiments is due to larger scale defects, such as cracks.

Publications resulting from study

Wilson, M. A.; and Pohorille, A.: The Thermal Conductivity of Cometary Ice. In preparation, 1996.

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1. Ramires, M. L. V.; de Castro, C. A. Nieto; Nagasaka, Y.; Nagashima, Q.; Assael, M. J.; and Wakeham, W.A.: Standard Reference Data for the Thermal Conductivity of Water. J. Phys. Chem. Ref. Data, vol. 24, no. 3, 1995, pp. 1377–1381.

2. Kouchi, A.; Greenberg, J. M.; Yamamoto, T.; and Mukai,T.: Extremely Low Thermal Conductivity of Amorphous Ice: Relevance to Comet Evolution. Astrophys. J., vol. 388, Apr. 1, 1992, pp. L73–L76.

Keywords
Thermal conductivity, Microporosity, Amorphous ice, Cometary ice

Ultrasensitive Detection of Atmospheric Free Radical Molecules: A Full-Sensitivity Demonstration Prototype

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Other personnel involved
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Objectives of the study
For the purpose of realizing a full-sensitivity demonstration prototype magnetic-rotation detector of free radical molecules in the Earth's atmosphere, to design and construct a multiple reflection optical cell contained in a solenoid magnetic field axially and radially uniform to ±5 percent.

A total optical path of 25 meters and small cell volume will give (1) parts per trillion detection sensitivity to free radical molecules in the Earth's atmosphere; and (2) spatial resolution of about 200 meters in the sky when the magnetic-rotation spectrometer is based on the DC-8 or ER-2 aircraft. This new technique offers advantages over currently used approaches in terms of much smaller weight and more easily interpretable results.

Progress and results
A multiple reflection optical cell contained in a solenoid magnetic field axially and radially uniform to ±5 percent has been constructed. The total optical path in the cell is about 25 meters. The optical ray trace of the cell is shown in figure 1. Except for the thin gold coating on the two end mirrors of the magnetic rotation cell, all the cell materials are nonmagnetic. The cell fits into a solenoid that is wound in such a manner as to produce a magnetic field uniform to within ±5 percent. The solenoid is pictured in figure 2 and measurements of the interior-axial magnetic field produced by the solenoid are shown in figure 3. The solenoid circuit can be operated at 1 kHz.

Significance of the results
With a 12-cm-long magnetic-rotation cell, parts per trillion sensitivity should be obtained for free radical molecular species.

Publications resulting from study
Blake, Thomas A.; Chackerian, Charles, Jr.; and Podolske, James R.: Prognosis for a Mid-Infrared Magnetic Rotation Spectrometer for the in situ Detection of Atmospheric Free Radicals. J. Applied Optics, vol. 35, no. 6, Feb. 20, 1996, pp. 973–985.

Keywords
Ultrasensitive detection, Free radicals, Magnetic rotation spectroscopy

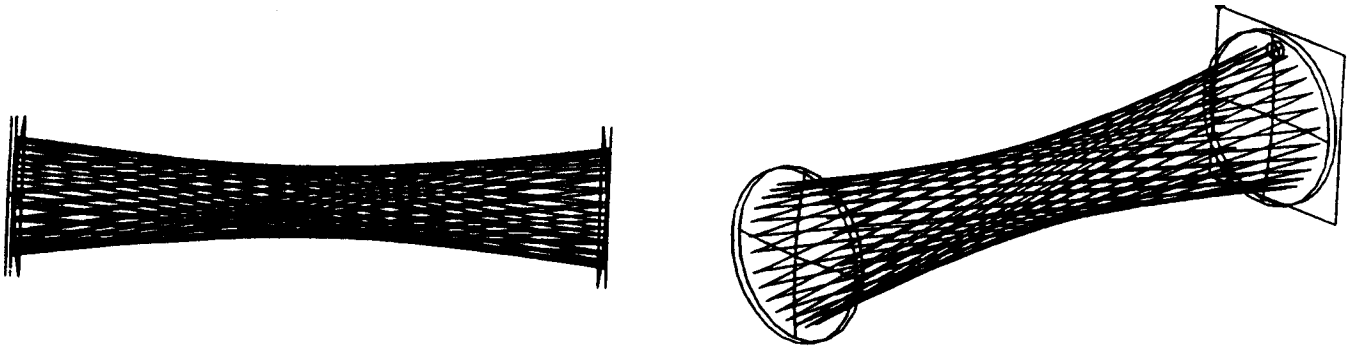

Figure 1. Light path in the Herriott cell with 58 passes and a mirror separation of 426 mm. The Herriott cell was designed with the aid of commercial optical design software and optimized for 58 passes. Mirror radius of curvature is 400 mm, and mirror diameter is 80 mm.

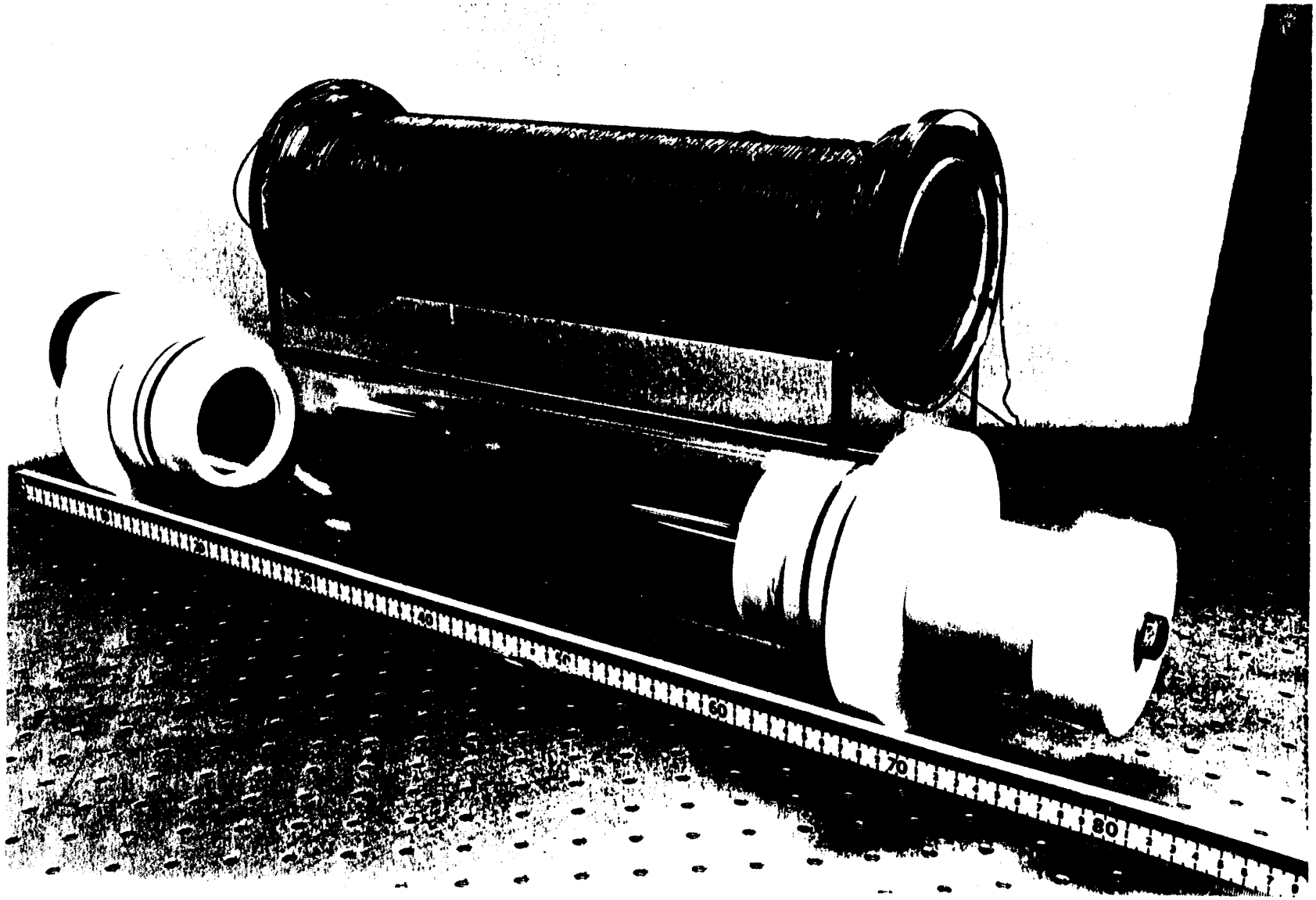

Figure 2. Solenoid.

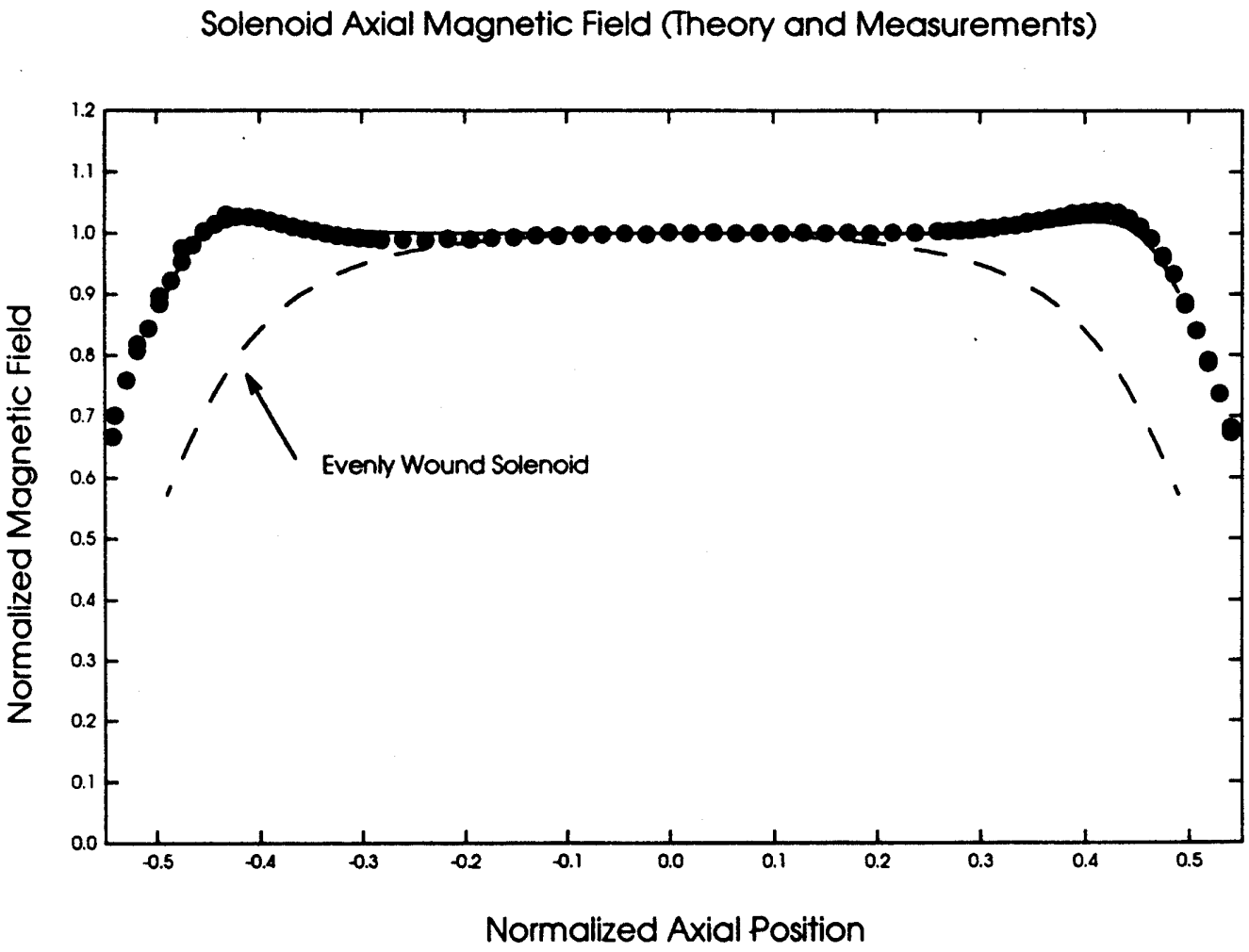

Figure 3. Solenoid axial magnetic field (theory and measurements).

Effects of Ozone Depletion/Ultraviolet Radiation on Plants

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Other personnel involved
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Objectives of the study
To identify indicators of ultraviolet (UV)-B radiation stress on plants so that this parameter can eventually be monitored by satellite remote sensing. It was assumed that current levels of UV-B radiation due to ozone depletion were high enough to perform the proposed experiments. The following hypotheses were tested: (1) production of screening pigments is stimulated by current levels of UV-B radiation; (2) node elongation is affected by UV-B radiation; (3) phenological stages (i.e., flowering) are controlled by UV-B radiation; and (4) plants grown under UV-B exclusion have higher chlorophyll concentration.

Progress and results
Stratospheric ozone is damaged by chlorine fractions of freon and other man-made gases as well as by some natural phenomena such as volcanic eruptions, which inject other ozone depleting molecules into the atmosphere. The current process of stratospheric ozone depletion has resulted in an estimated 15- to 20-percent increase of solar UV-B (280–320 nm) radiation reaching the Earth's surface. UV-B is known to affect molecules and biological systems. Plant physiological experiments have shown that exposure to enhanced UV-B radiation results in higher concentrations of epidermal pigments and breakage of chlorophyll and growth hormones. Insufficient knowledge of the effects of current levels of solar UV-B radiation on ecosystems impairs the use of NASA's technology [land satellite (LANDSAT) and the Earth Observing System (EOS) programs] to establish monitoring routines to identify areas of risk and develop protective and remedial actions.

Alfalfa (*Medicago sativa l.*) was selected for these experiments because it is an important crop that provides forage for many domestic animals, and because it is representative of plants that exhibit the C3 or "cool season" photosynthetic pathway. A synchronous culture of alfalfa plants from the same genetic stock was grown and brought to maturity in an open growth chamber with no exposure to UV-B radiation. Mature plants were transplanted to the field UV- shed and put under observation for eight weeks. The UV shed consists of a wooden frame enclosed with chicken wire to protect plants from herbivores, and two chambers. One chamber is fitted with cellulose acetate (15-percent UV reduction); the second chamber is covered with polyester (UV-B exclusion). Plants are enclosed by these screening sheets, but the lower part of the shed is open, allowing air circulation and minimizing the microclimatic effects. Soil, water, and other factors are identical in both chambers.

Along with the experiments, spectroradiometric readings were taken; they showed measurable amounts of UV-B at ground level, ranging from 206 to 320 nm with maxima of 0.021 watt per square centimeter at 320 nm. Vacuolar pigments were present in plants grown under both conditions, but concentration was higher in plants exposed to UV-B. Internodal distances of plants under UV-B exclusion were significantly larger during the weeks of July 11, 18, and 25. In the week of August 1, internodal distances were similar in both treatments, and at the end of the experiment, plants under 15-percent UV reduction had longer internodes. By July 25, plants under UV-B exclusion were approximately 20 percent bigger, had longer stems and larger leaves, and the chlorophyll content of the leaves was higher than in plants under 15-percent UV reduction. By August 1, plants under UV-B exclusion were blooming and became senescent rapidly. By contrast, plants under 15-percent UV reduction had fewer flowers and remained alive and productive until August 15. Chlorophyll concentration was higher under UV-B exclusion in the weeks of July 11 and 18. Then, concentrations under both treatments were similar, and at the end of the experiment, plants with 15-percent UV reduction had higher concentrations of chlorophyll and were beginning to enter the flowering stage.

Shielding plants differentially produced the results detailed in the previous paragraph. These results make a strong case for using solar radiation alone to evaluate the effects of increased UV-B flux due to stratospheric ozone depletion. Flavonoid pigments were found in higher concentrations in plants exposed to solar UV-B (hypothesis 1). However, plants that were never exposed to UV-B also had significant amounts of flavonids, suggesting that

alfalfa plants have this built-in protective mechanism. By August 1, growth (node elongation, hypothesis 2) was altered in plants exposed to UV-B. Then plants overcame the stress and developed well, while plants with no UV-B grew less and entered the following phenological phase earlier. Growth depends on indoleacetic acid (IAA), which absorbs in the UV-B range and is rapidly destroyed by light. High concentrations of IAA under UV-B exclusion are possibly generating a synergistic effect with other hormonal systems, causing those plants to flower sooner. Plants under UV-B exclusion initiated the flowering stage (hypothesis 3) earlier, probably because of higher concentrations of gibberellic acid. The first third of this experiment showed higher chlorophyll concentrations under UV-B exclusion than under 15-percent UV reduction (hypothesis 4), suggesting that the photosynthetic apparatus is more vulnerable to UV-B damage before the plants fully acclimate to field conditions. Synchronous changes that occurred about August 1 suggest that repair mechanisms for UV-B-target systems exist and that "normal" amounts (i.e., 15 percent lower than current values) of UV-B radiation may control hormonal balances and the resulting synergistic effects of growth, photosynthesis, flowering, seed production, and death. The proposed hypotheses were validated for alfalfa, but new questions arose, suggesting that more research is needed before a strategy can be devised to use NASA's technology for monitoring, early detection, and policy making applications regarding solar UV-B stress on natural and crop communities.

Significance of the results

The hypotheses were validated for alfalfa and the results demonstrated that more research is needed before a strategy can be devised to use NASA's technology (LANDSAT and forthcoming EOS) for monitoring, early detection, and policy-making applications regarding solar UV-B stress on plants and the economic consequences. This project demonstrated that plants under UV-B stress produce signals that can be extrapolated to plant communities. However, the strongest signal (chlorophyll concentration) needs to be decoded in physiological terms (i.e., ability to capture carbon in the gas exchange process and excitation condition of the chlorophyll molecule under increased UV-B flux). Further work is needed to discriminate between signals produced by UV stress and those produced by seasonal and climatological variables. Future work will allow investigators to use NASA's suite of remote sensing instruments to determine UV stress on a large scale.

Publications resulting from study

Materials are being prepared for publication.

Keywords

Alfalfa, Plant stress physiology, UV-B radiation

Return to the Red Planet: Remote Sensing Analog Studies as Preparation for Mars Exploration Exobiology

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Objectives of the study
To define basic spectral and spatial resolution requirements necessary for identifying discrete aqueous mineral deposits from Mars orbit. Aqueous deposits of various types are given high priority as targets for Mars exopaleontology, that is, in exploring for evidence of an ancient Martian biosphere. To effectively target sites on Mars for future landed missions and sample return, identification of such deposits from orbit must be made with confidence. This study utilized high spectral and spatial resolution infrared (IR) spectral data to establish realistic thresholds for spatial and spectral resolution. This information is being used to define nominal instrumentation requirements for future missions for Mars exopaleontology.

Progress and results
The perspective gained from this study helped us to convince the Mars '01 Science Definition Team and the Mars community at large of the need for a mission to obtain high spatial resolution (<100 m/pixel) IR imaging of key exobiology sites during the 2001 mission opportunity to support site selection for the 2003 mission and a sample return in 2005.

Significance of the results
As has been mentioned, the high spatial resolution IR spectrometer has now been included in the announcement of opportunity (AO) for 2001. Results also influenced the path of technology development taken by the digital array scanning interferometer (DASI), an IR mapping version of which will be proposed by an Ames team for the 2001 orbital mission. The data acquired are being analyzed.

Keywords
Mars, Martian life, Mono Basin

Development of Noninvasive, Tissue-Oxygen Sensor for Optimizing Ergonomic Design of Workstations in Space and on Earth

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Objectives of the study
Repetitive motion disorders of the hand and forearm are caused by repeated exertion of a specific muscle, tendon, or joint. Such repeated activities, over time, may increase local tissue fluid pressure, decrease local blood flow and tissue oxygenation, and cause pain and functional deficits of the involved limb (refs. 1 and 2). Examples of repetitive motion disorder are carpal tunnel syndrome (CTS) and epicondylitis. In Santa Clara County, California, alone, over 7000 cases of CTS were reported in 1988 (ref. 3). At present there is no *noninvasive method* to monitor local tissue stress and its impact on tissue oxygenation. Such techniques will help improve designs of keyboards, gloveboxes, and other workstations to prevent carpal tunnel and other work-related syndromes.

A current procedure for studying CTS and monitoring local tissue stress is to measure tissue fluid pressure by catheter insertion (refs. 4–6). Because of the invasive nature of this technique, application of this procedure to evaluate risk factors for jobs and tasks is difficult. If tissue oxygenation can be accurately measured noninvasively, it may be a valuable tool for identifying tasks/tools with high risk for repetitive motion disorders. Dual-wave near-infrared (NIR) spectrophotometry (NIRS) is a noninvasive technique that exploits the disparity between absorption spectra of oxy- and deoxyhemoglobin to measure changes in tissue oxygenation (fig. 1). A disadvantage of the NIRS technique is that currently available probes are designed for penetration to tissue depths of 2–3 cm only and consequently are inappropriate for monitoring small, more superficial muscles such as the extensor muscles of the forearm. Therefore, the objectives of this investigation are to modify the currently existing probe such that superficial muscles can be studied, and to determine whether NIRS can be used to quantify oxygenation at low levels of muscle loading. Low levels of prolonged static contraction of the upper extremity [less than 20 percent maximum voluntary contraction (MVC)] are common in many occupational settings (ref. 7).

Progress and results
The NIRS probe consists of two light sources and a detector. The light sources (tungsten filament lamps) emit light into tissue. Light is scattered randomly within the tissue; some of it is absorbed by the tissue and some reflects back to the photodetectors located on the probe. The probe, which illuminates the sample tissue, is designed to penetrate to depths of 2–3 cm. However, the extensor muscle belly of the forearm lies only 1–2 cm beneath the skin. One way to reduce the photon penetration depth is to decrease the light source to detector distance. The probe was redesigned so that the distance between the light source and the detector was adjusted to allow light penetration through a tissue depth of 1–2 cm below the skin.

Using the modified adjustable probe, tissue oxygenation was measured in nine subjects in the extensor forearm muscle during one minute of relaxation. Subjects were seated with right arms abducted to 45°, elbows flexed to 85°, right forearms pronated 45°, and wrists and forearms supported on an arm rest throughout the protocol (fig. 2). Four different loads were then applied just proximal to the dorsal hand such that subjects isometrically contracted the extensor muscle at 5, 10, 15, and 50 percent of maximum voluntary contraction for one minute each. A three-minute recovery period followed each contraction level. At the end of the protocol, with the NIRS probe still in place, the minimum value of TO_2 was averaged over three seconds at the point of exhaustion and this result was considered physiological functional zero. Hence the minimum TO_2 value obtained during this tourniquet application to the arm was set to be 0-percent TO_2. Consequently, for each level of contraction and for each subject, TO_2 was normalized to baseline (100-percent TO_2) and ischemia (0-percent TO_2). The mean TO_2 decreased from resting baseline (100-percent TO_2) to 89 ± 4 percent (SE),

81 ± 8, 78 ± 8, and 47 ± 8 percent at 5-, 10-, 15-, and 50-percent MVC, respectively (fig. 3). TO_2 levels at 10-, 15-, and 50-percent MVC were significantly lower ($p < 0.05$) than baseline value. Results of this study indicate that TO_2 significantly decreases during brief, low levels of static muscle contraction and that the modified probe is a valuable noninvasive tool for detecting deoxygenation at low levels of forearm muscle contraction.

Significance of the results

The adjustable probe enables the study of superficial muscles such as the forearm extensors. Work-related upper extremity injuries/disorders account for 24 percent of the total lost time injuries in 1994 (Bureau of Labor Statistics, 1996). Musculoskeletal disorders of the upper extremity pose a major problem in many occupations involving repetitive hand motions (ref. 7). Moreover, in most of these occupations, low levels of repetitive and sustained muscle loading are a major risk factor in causing muscle fatigue and pain. Typists and computer operators, for example, exert about 10 percent MVC (ref. 8). However, when such a small magnitude of force is exerted for a prolonged period of time, muscle edema and deoxygenation may occur.

Astronauts will work for prolonged periods of time in gloveboxes during tours of duty aboard Space Station, as well as on interplanetary missions. Because of physiological changes in the upper extremity experienced in microgravity, including a lowering of blood pressure and local swelling, astronauts also performing low levels of repetitive and sustained activity may be at increased risk for developing muscle fatigue and pain during prolonged spaceflight. In addition, problems with hands have begun to be identified in extravehicular activity (EVA)-related tasks. Evidence indicates that some astronauts have difficulty donning their EVA gloves because of hand swelling while working in their space suits (Bruce Webbon, personal communication). Swelling and possible decreased oxygen transport to muscles are important factors that predispose crew members in space to hand fatigue, pain, and dysfunction.

The long-term goal of this research is to improve work environments through the development and verification of this noninvasive device for understanding the role of oxygen in work-related repetitive motion disorders and for improving workstation designs on Earth and in space.

Publications resulting from study

Murthy, G.; and Hargens, A. R.: Near Infrared Spectroscopy: A Noninvasive Technique for Diagnosing Exertional Compartment Syndrome. Operative Techniques in Sports Medicine, vol. 3, no. 4, 1995, pp. 256–258.

Murthy, G.; Kahan, N. J.; Hargens, A. R.; and Rempel, D. M.: Forearm Muscle Oxygenation Decreases with Low Levels of Voluntary Contraction. Submitted to J. Orthopaedic Research, 1996.

Hargens, A. R.; Ballard, R. E.; Wilson, M.; Torikoshi, S.; Murthy, G.; Breit, G. A.; Watenpaugh, D. E.; Kawai, Y.; and Yost, W. T.: Noninvasive Intracranial Pressure and Tissue Oxygen Measurements for Space and Earth. Presented at Life Sciences and Space Medicine Conference, Houston, Tex., April 3–5, 1995, pp. 130–131.

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Keywords
Muscle oxygenation, Near-infrared spectrophotometry, Repetitive motion disorders, Work station design

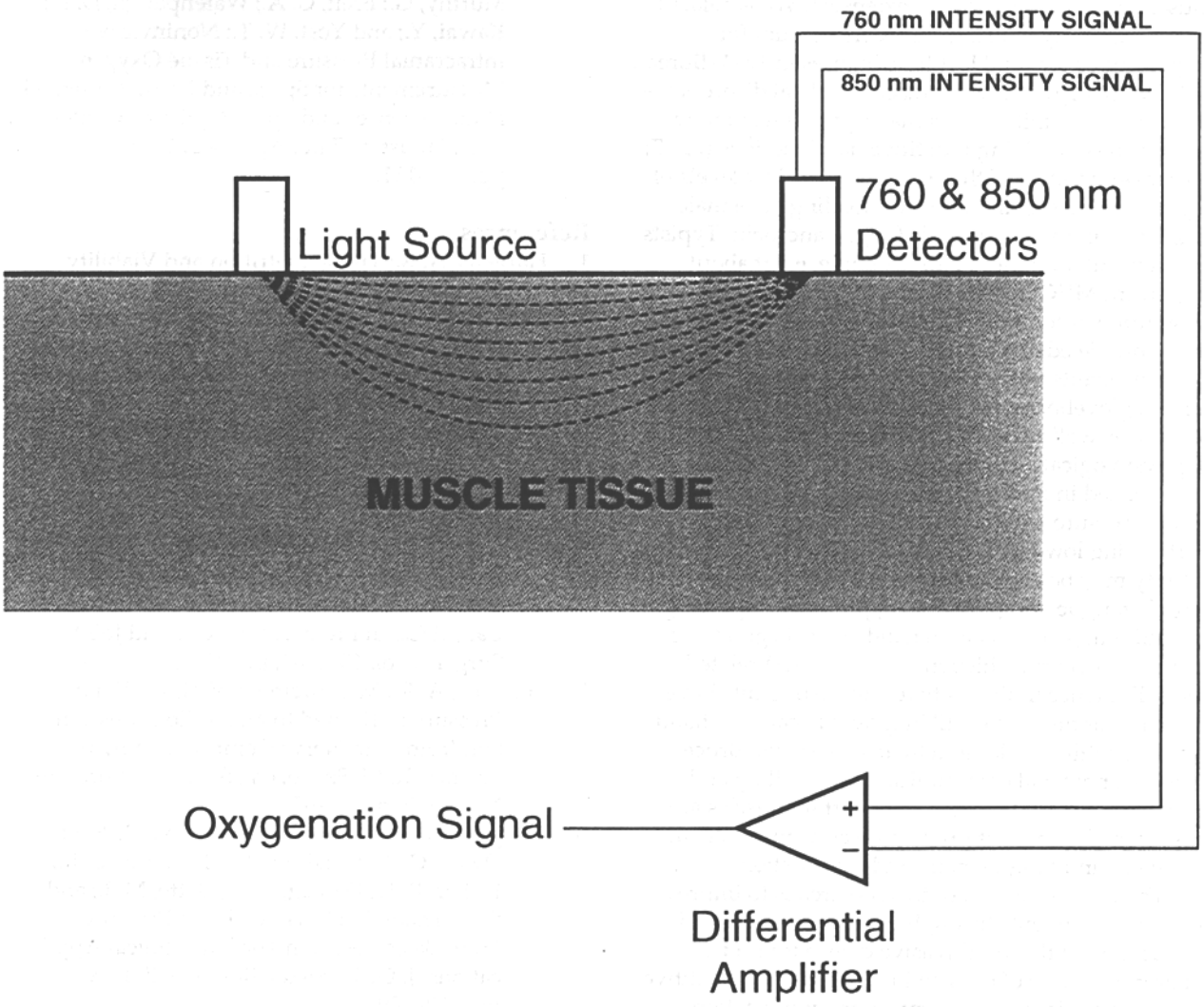

Figure 1. A schematic of the NIR spectrophotometer. Infrared (IR) energy emitted by the light source is scattered randomly within the tissue and sensed by two photodetectors that filter 760- and 850-nm wavelengths. The optical density of blood hemoglobin at these wavelengths is dependent on the oxygenation state. The depth of light penetration is a function of separation between the light source and the detectors.

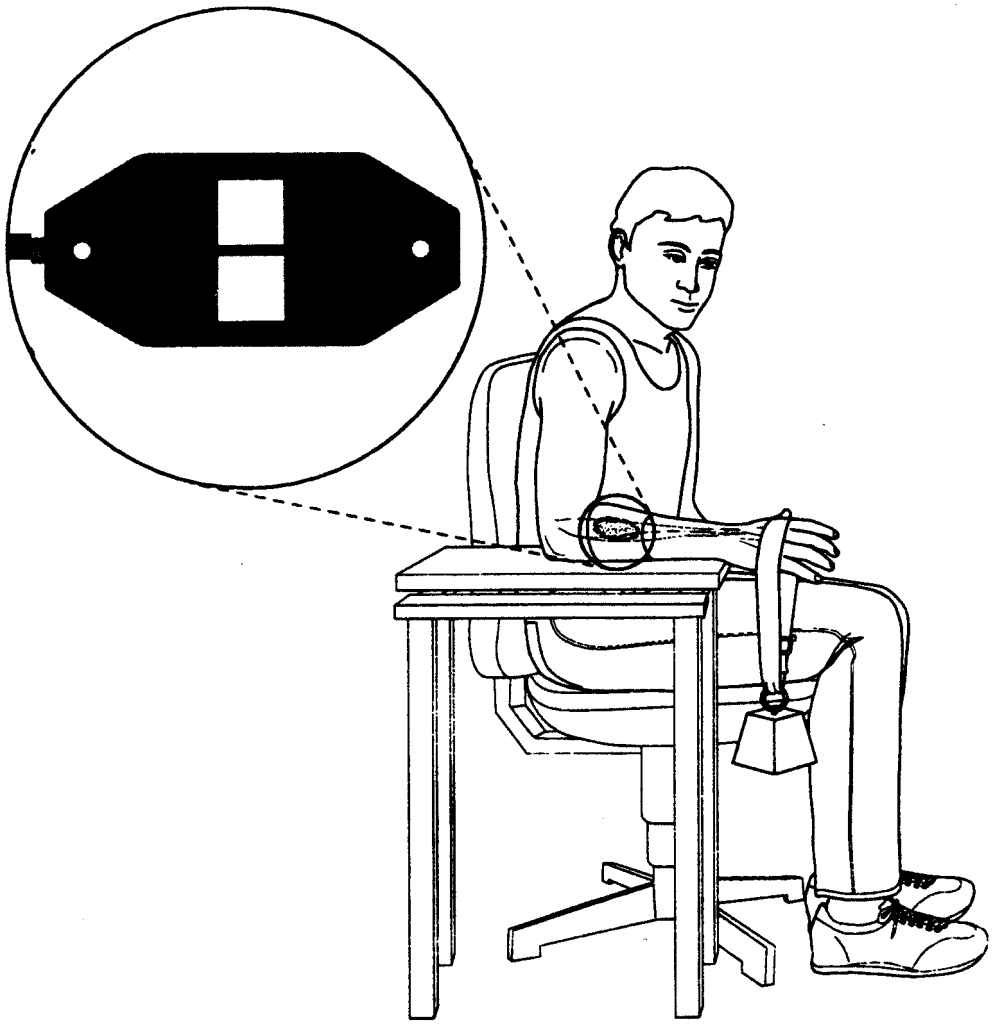

Figure 2. The NIR spectroscopy probe over the forearm muscle, which detects muscle oxyhemoglobin and oxymyoglobin. The inset illustrates the underside of the probe, which consists of a light transmitter on each end along with 760- and 850-nm wavelength detectors in the middle of the probe.

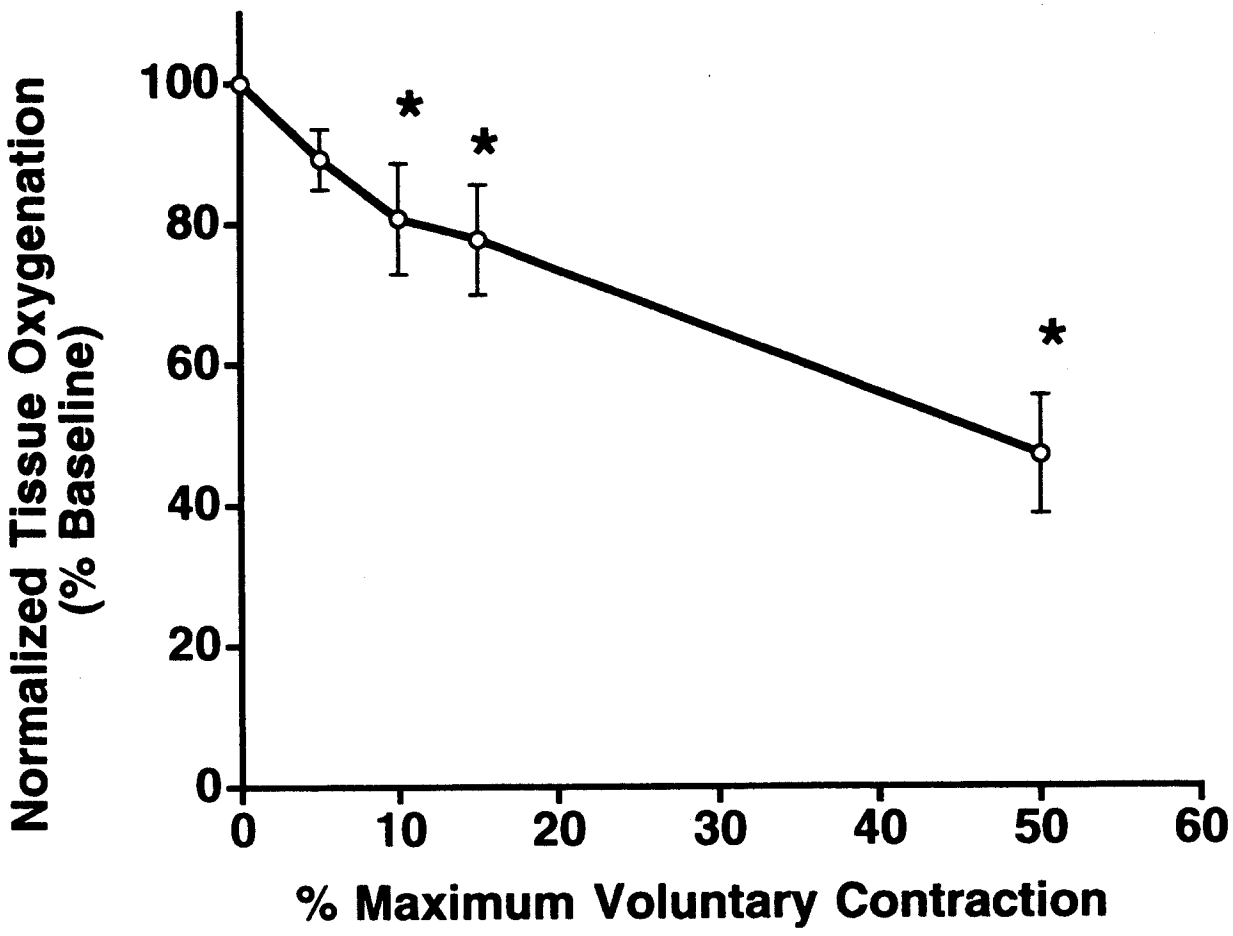

Figure 3. Normalized muscle oxygenation during 5-, 10-, 15-, and 50-percent maximum voluntary contraction.
** denotes significantly lower ($p < 0.05$) value than baseline.*

A Novel Telemetric Biosensor to Monitor Blood pH Online

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Objectives of the study
Presently, there are no known wireless telemetric devices that allow chronic, in vivo measurements of chemical parameters such as pH. NASA needs such devices to better understand physiological changes induced by the space environment. The medical community needs this capability as a monitoring and diagnostic tool with ambulatory and fetal patients. The objectives of this study were threefold: 1) to design, fabricate, and test a miniaturized pH sensor for chronic, online monitoring of blood and tissue pH levels; 2) to modify an existing, totally implantable biotelemeter to acquire, process, and transmit the pH signals; and 3) to perform in vivo testing of the pH sensor and biotelemeter.

Progress and results

pH Sensor
The pH sensor consists of two single lumen catheters (physically combined or separated); one lumen each for the reference and indicator (ion selective) electrodes. (See fig. 1.) The indicator electrode incorporates a solvent, polymeric H^+-sensitive neutral carrier membrane cast around the tip of a microbore polyvinyl chloride (PVC) catheter. The membrane composition includes a high molecular weight poly (vinyl chloride) used as a support matrix, bis (2-ethyl hexyl) adipate used as a plasticizer, potassium tetrakis (4-chlorophenyl) borate used as a lipophylic salt, and tri-n-dodecylamine used as the H^+ ionophore. The reference electrode includes a biocompatible hydrogel frit and produces a stable reference potential when making a pH measurement.

The test microbore pH sensors exhibit response characteristics similar to larger, commercially available pH electrodes. Baseline drift is small, on the order of 1–2 mV (0.01–0.03 pH units) per 24 hours [fig. 2(a)], and decreases with electrode age. Sensor sensitivity is linear between pH 4 and 9 and slopes fall between 55 and 59 mV/pH units at room temperatures. (Theoretical = 59.16 mV/pH @ 25°C.) [See fig. 2(b).] Sensitivities are very stable, drifting only 1 to 2 percent over a 7-day period. Response times are rapid, with approximately 95 percent of the response achieved within less than 3 seconds [fig. 2(c)].

Extensive testing following implantation in rats has revealed that the test pH sensors retain much of their capability for accurate electrochemical analysis after as long as 21 days of subcutaneous implantation. Electrochemical performance characteristics including drift, sensitivity, selectivity, and response time were not significantly compromised by implantation and were not different from bench top controls. (See fig. 3.)

A rat acidosis model has been developed to evaluate the in vivo performance of implanted sensors. Rats with an indwelling jugular vein catheter are purchased. Respiratory acidosis is induced by exposing the rat to a 7-percent CO_2 atmosphere for up to 10 minutes. To evaluate the performance of implanted sensors, blood samples are taken during exposure. Blood is measured with a benchtop analyzer and compared to the readings of the implanted sensor. Preliminary tests indicate that the test pH sensors accurately measure changes in pH in rat subcutaneous tissue. (See fig. 4.)

Biotelemetry
A totally implantable, digitally encoded biotelemeter for measurement of pH, temperature, and heart rate has been designed, prototyped, and successfully bench tested in conjunction with the test microbore pH electrode. The circuit employs a low-power analog-to-digital (A/D) converter, a digital-encoding integrated circuit (IC) (Manchester) and transmits a pulse-modulated 455-kHz carrier. It dissipates less than 120 μA. The device has been successfully miniaturized in thick film hybrid form and will be packaged with a 3/4-ampere-hour battery inside a biocompatible ceramic enclosure (fig. 5). A portable receiver acquires and demodulates the radio frequency (RF) carrier, demultiplexes and decodes the 4 data channels, and presents the output to liquid crystal displays (LCDs)

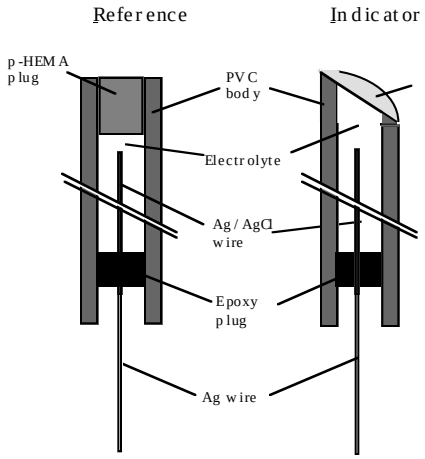

Figure 1. Physically separated pH indicator and reference electrodes based on a single lumen PVC-based microbore catheter.

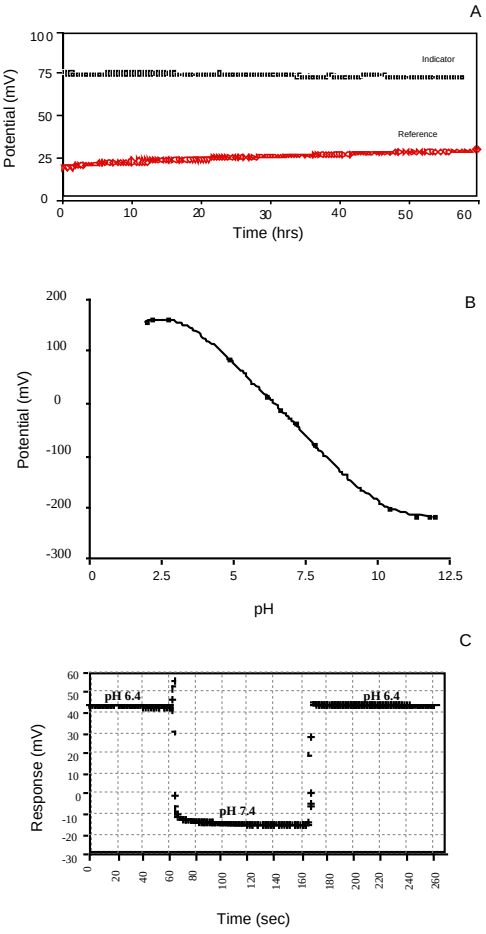

Figure 2. (a) Example of indicator and reference electrode stability over 60 hours in a standard buffer solution; (b) response sensitivity (slope in mV/pH) for a representative pH electrode; and (c) sensor response in pH 6.4 and 7.4 buffer solutions.

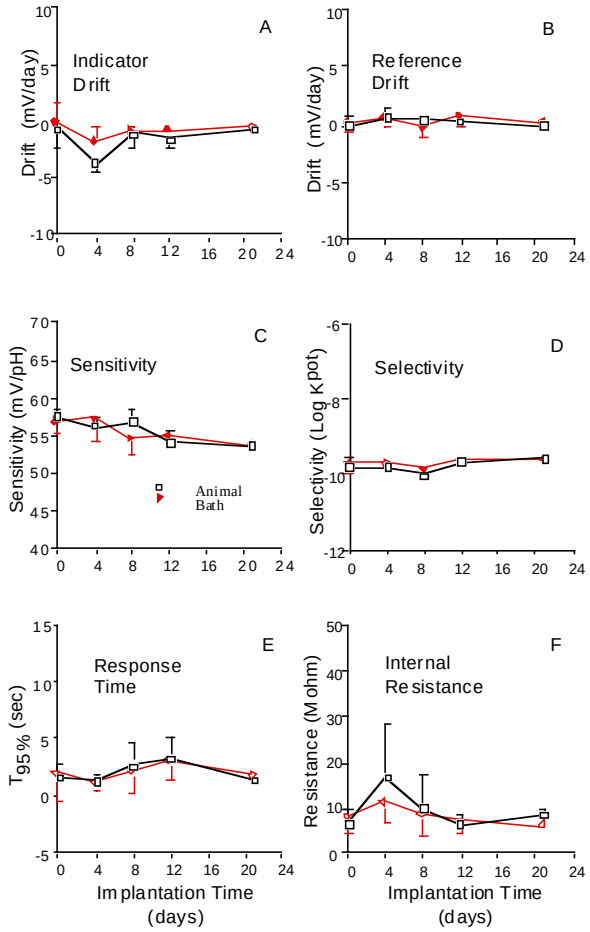

Figure 3. Post-implant time histories of mean (a) indicator drift; (b) reference drift; and (c) sensitivity; (d) selectivity; (e) response time; and (f) internal resistance of indicator electrode.

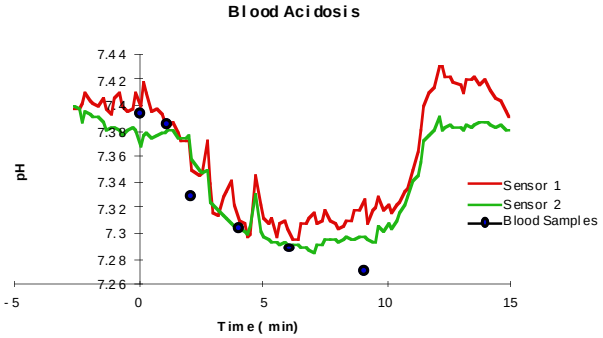

Figure 4. Changes in pH for a single rat exposed to a 7-percent CO_2 atmosphere for 10 minutes. Measures were taken every 10 seconds from sensors 1 and 2, which were implanted subcutaneously 3 hours earlier (baselines have been adjusted to correct for drift). Blood pH measures were obtained from blood samples acquired from the jugular vein catheter.

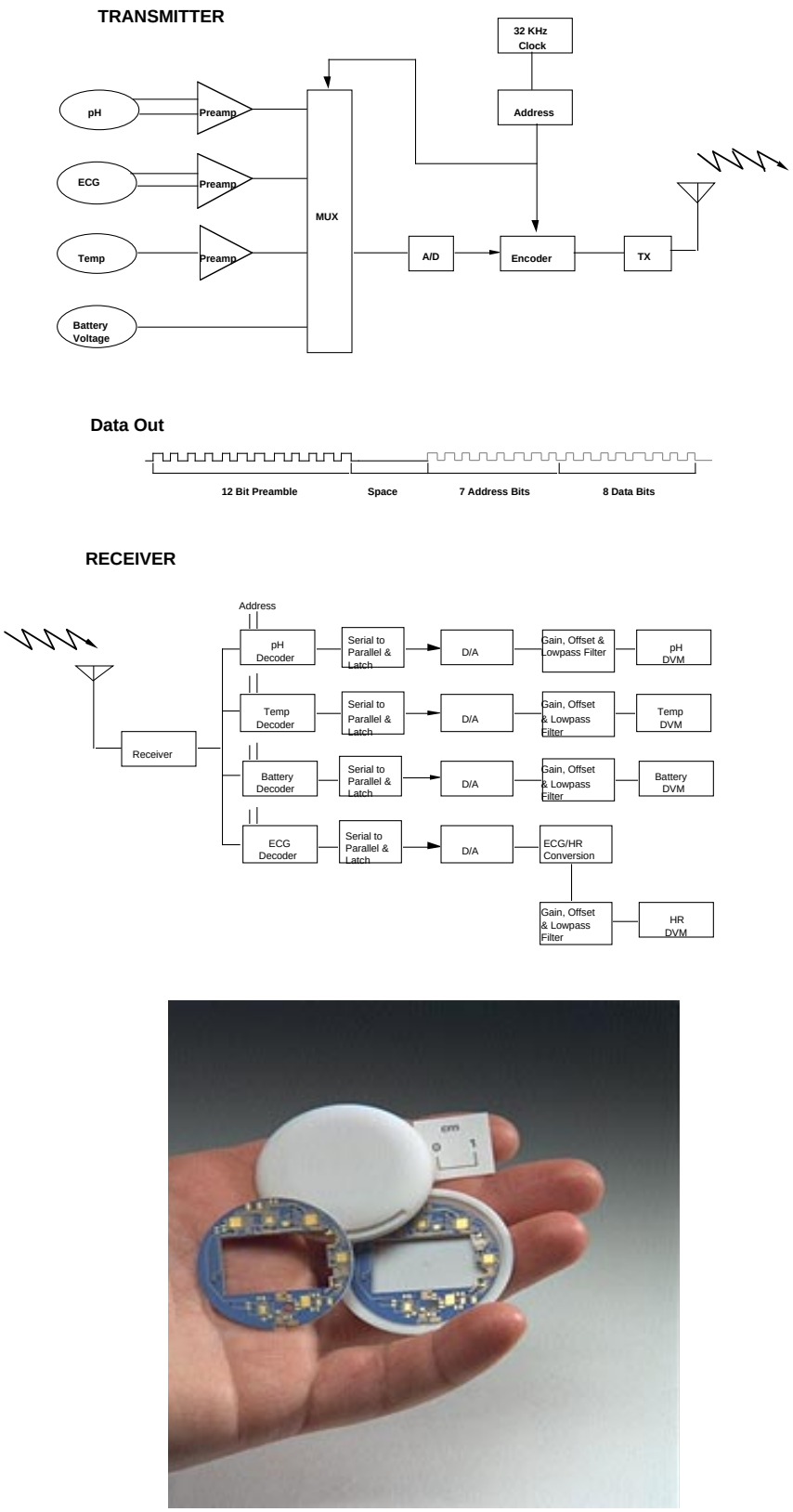

Figure 5. Block diagram of the digitally encoded biotelemetry system and picture of the implantable biotelemeter.

on the front of the receiver chassis. A prototype receiver has been successfully tested with implants in sheep.

Significance of the results

Biotelemetry system components including a miniaturized, neutral carrier-based pH probe, a totally implantable, digital biotelemeter, and a portable, easy-to-use receiver have been successfully designed, fabricated, and tested. Remaining integration and testing of these components will be completed in the near future. Initial application of this technology will be to improve human fetal monitoring at the University of California, San Francisco's Fetal Treatment Center. Ultimately, the technology will be used with animal models on the Space Shuttle and Space Station to further understand physiological adaptation to the space environment.

Publications resulting from study

Hines, J. W.; Somps, C. J.; Ricks, B.; and Kim, L.: Advanced Biotelemetry Systems for Space Life Sciences: pH Telemetry. In proceedings of the 13th International Symposium on Biotelemetry, Williamsburg, Va., Mar. 26–31, 1995, pp. 131–137.

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Keywords

pH sensor, Biotelemetry, Ion selective electrode, Rat

Global Climate Change: The Role of Electron-CO_2 Collisions in the Cooling of the Thermosphere

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Progress and results

Carbon dioxide belongs to the group of infrared absorbing molecules in the atmosphere known as greenhouse gases. It absorbs radiation at a 15-micron wavelength, in the (7- to 15-micron) range known as the atmospheric window. It is so named because radiation absorption in that range of wavelengths is rather weak. Changes in this window due to either man-made or natural causes will have detrimental effects on our climate. Increased concentrations of greenhouse gases caused by human activities such as burning fossil fuels tend to close the atmospheric window. One such example is CO_2, whose concentration has been steadily increasing.

To understand the effect of increased CO_2 concentration on the climate, it is necessary to understand the microscopic mechanism of heat absorption and heat loss by CO_2. It is known that the heat exchange mechanism of CO_2 is different in the troposphere and thermosphere. In the troposphere, CO_2 in its ground vibrational level is excited to the first excited level of the v_2 bending mode, (010), by infrared absorption. It is subsequently quenched by collisions with other atoms or molecules, and the radiation energy absorbed by CO_2 is converted to kinetic energy, resulting in tropospheric warming. In the stratosphere and above, particle densities become significantly lower, and therefore, collisional quenching is much less frequent. In that region of space, the fine-structure changing collision of oxygen atoms with CO_2 is effective in exciting CO_2 to the (010) mode. Because of the lower density in the upper atmosphere and the fact that it is optically thin, radiation instead of collisional quenching is the major dissipation mechanism. The result is thermospheric cooling. (See ref. 1.) Thus increased CO_2 concentration has opposite effects in the troposphere and thermosphere.

It is known that in the past decade the mesosphere has already cooled down by 3 to 4 K and the mesopause has cooled by 6.5 K. The cooling exceeds the prediction of references 2 and 3, indicating that an additional cooling mechanism is possible. Furthermore, there is a discrepancy of a factor of six in the vibrational excitation rate of CO_2 by O atoms between the rocket measurements of reference 4 and the laboratory measurements of reference 5. The latter discrepancy points to the possibility that mechanisms other than collision with O atoms may be responsible for generating excited CO_2 in the thermosphere. The higher density of CO_2 will in turn explain the larger cooling observed.

The present study concentrates on the mechanism of creating vibrationally excited CO_2 by electron impact in the thermosphere. The method of references 6 and 7 was used for the scattering calculation. In order to describe the proper energy dependence of the incoming and scattered electron near threshold, the energy modified adiabatic (EMA) approximation (ref. 8) has been incorporated. Both the target wavefunction and the scattering wavefunction employ the correlation-consistent triple zeta basis of references 9 and 10, supplemented by two diffuse s and p functions. Electron-target polarization effect is described by the polarized orbital approach (ref. 11). EMA T-matrices were calculated at bond angles of 165, 150, and 140 degrees while maintaining the equilibrium bond lengths. (Note that transition to the bending mode is forbidden at 180 degrees.) Harmonic oscillator functions are used for vibration.

Figure 1 presents the calculated vibrational excitation cross section of the (010) bending mode of CO_2. The cross section at threshold arises rapidly, but not as sharp as predicted by the Born approximation, which is a first-order approximation and significantly less accurate than the present approach. The present study also found that the excitation cross section near threshold is dominated by the p wave to s wave excitation.

Future plans include validating the threshold result by carrying out a corresponding calculation using the finite-element Z-matrix method. The cross sections will then be used to derive the excitation rate constant for thermospheric modeling.

Publications resulting from study

Huo, Winifred M.: Global Climate Change: The Role of Electron-CO_2 Collisions in the Cooling of the Thermosphere. Paper presented at the 49th Annual Gaseous Electronics Conference, Argonne National Laboratory, Argonne, Ill., Oct. 20–24, 1996.

Huo, Winifred M.: Low-Energy Electron Impact Excitation of the (010) Bending Mode of CO_2. Abstract in Bull. of the Am. Phys. Soc., vol. 41, no. 6, 1996, p. 1313.

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Keywords

Thermospheric cooling, Carbon dioxide, Electron impact

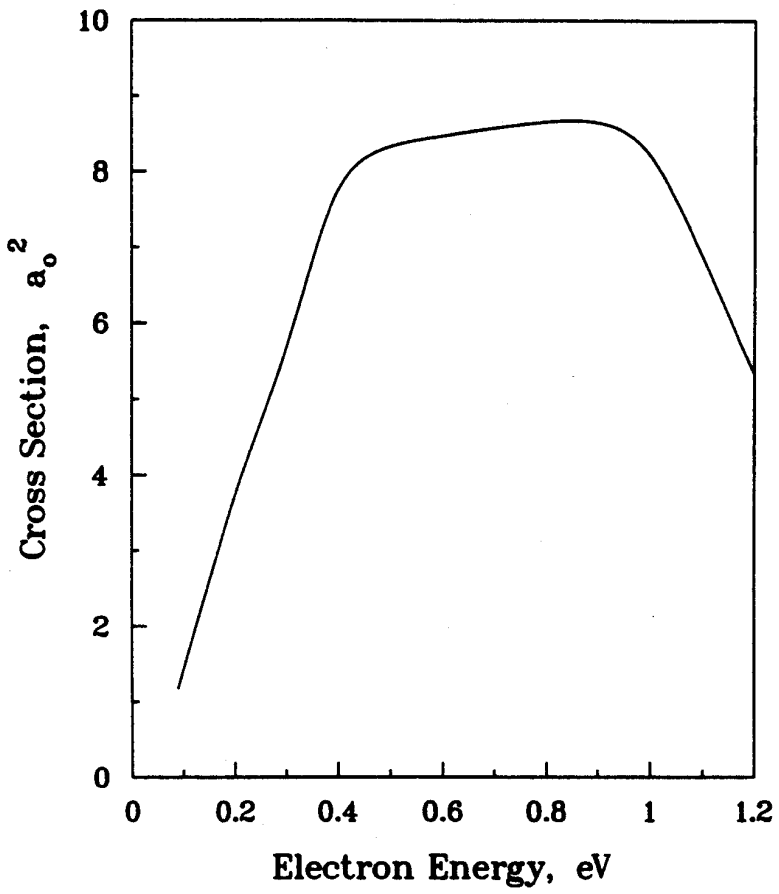

Figure 1. e-CO_2 (010) excitation cross section.

Understanding Ion Mobility in Polymer Electrolytes for Lithium-Polymer Batteries

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Objectives of the study
To develop a molecular-level understanding of the lithium ion transport process in poly(ethylene oxide) gels used as the electrolyte in lithium-polymer batteries. Such an understanding is critical to the design of optimal lithium-polymer batteries for aerospace, automobile, and electronics applications. Ab initio quantum chemistry calculations were used to determine the nature of the Li^+-polymer interaction and molecular dynamics simulations performed on ion-polymer systems to probe the ion transport mechanism. The simulations can be carried out to determine the rate of ion transport as a function of temperature, ion concentration, polymer cross-link density, and identity of the anion.

Progress and results
The first year of this project was spent determining an accurate force field for use in the molecular dynamics simulations of the ion-polymer systems. A previously determined force field for the polymer, poly(ethylene oxide) or PEO, was used to perform ab initio quantum chemistry calculations to determine the geometries and energetics of complexes involving Li^+ and model ether molecules such as dimethyl ether and dimethoxyethane (DME).These calculations were carried out using standard computational chemistry methods. However, one novel feature was the use of a specially derived basis set for Li^+, which produced results that are significantly more accurate than ones obtained previously. The interaction of the cation with up to four ether molecules was studied to determine the effects of multiple solvation. The interaction of Cl^- and I^- anions with Li^+ and with the model ethers was also studied. During the second year of the project those results were extended to a more complex anion (PF_6^-).

The quantum chemistry results were fit to atom-ion and ion-ion pairwise functions to represent the ion-ether interactions in a form suited for use in molecular dynamics simulations. When combined with previous work for PEO, this represents the so-called force field. In order to match the quantum chemistry results, terms in the force field were included to represent polarization effects in addition to the standard coulomb, dispersion, and steric repulsion terms.

Using this force field, molecular dynamics simulations were performed for a very dilute lithium salt-polymer system, consisting of 32 H-(CH_2-O-CH_2)$_{12}$-H polymer chains and 10 Li^+ and 10 Cl^- ions at a temperature of 450 K. The results of these simulations indicate that, on average, each Li^+ is solvated by a total of 8 oxygen atoms from 2 different polymer chains. The presence of the Li^+ slows the self-diffusion rate of the PEO. The Li^+ and polymer have identical diffusion coefficients. On the other hand, the Cl^- anion moves much more rapidly through the polymer because it does not interact as strongly with other species.

A concentrated lithium iodide-polymer system (one Li^+ for every five PEO oxygen atoms) was considered for a temperature of 360 K. Through collaboration with scientists at the Oak Ridge National Laboratory, Oak Ridge, Tennessee, neutron scattering experiments were carried out on the same salt-polymer system *at the same concentration and temperature.* After calibration of the polarization terms in the force field, quantitative agreement was found between the experimental and theoretical pair distribution functions. Therefore, the simulations are accurately modeling concentrated solutions of LiI in PEO. Analysis of these simulation results is continuing; at this concentration, the Li^+ was found to be solvated by 4 oxygen atoms. When the analysis is completed, information about ion transport in concentrated lithium salt-polymer solutions will be obtained.

Significance of the results
The quantitative agreement between simulation results and experimental scattering data demonstrate the accuracy of the present approach. Simulations, based on the force field used in present testing, can be

used with confidence to predict the properties of lithium-polymer electrolytes. A Space Act Agreement is being negotiated with a major battery manufacturing company for follow-up work. If this project is continued it will be used to *predict* how changes in the electrolyte composition might improve battery performance.

Publications resulting from study

Smith, G. D.; Jaffe, R. L.; and Partridge, H.: A Quantum Chemical Study of the Interactions of Li^+, Cl^-, and I^- Ions with Model Ethers. J. Phys. Chem., in press.

Smith, G. D.; Borodin, O.; Pekny, M.; Annis, B.; Londono, D.; and Jaffe, R. L.: Polymer Force Fields from ab initio Studies of Small Model Molecules: Can We Achieve Chemical Accuracy? Submitted to Spectrochemica Acta.

Keywords

Polymer electrolytes, Ion diffusion, Molecular dynamics

Nonlinear Interactions between Background Disturbances and Disturbances Generated by Laminar Flow Control (LFC) Devices

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Objectives of the study

Considerable fuel savings could be realized by maintaining laminar flow over a wing surface. However, detrimental nonlinear interactions can occur between background disturbances and disturbances introduced by laminar flow control (LFC) devices such as suction holes. Almost nothing is known about these interactions. At an even more fundamental level, advanced codes, e.g., parabolized stability equation (PSE) methods, are being used to predict transition on full-scale aircraft. The most likely disturbances in the boundary layer will be three-dimensional (3-D). Although the behavior of two-dimensional (2-D) disturbances is well understood, there has not been satisfactory experimental validation of these codes for *the simplest possible form of 3-D disturbance in the simplest possible flow*, i.e., the harmonic point source in a 2-D Blasius boundary layer.

The primary objective of the project is to gain a fundamental understanding of the nonlinear interactions between background disturbances in laminar boundary layers, e.g., longitudinal vortices (Klebanoff modes) and disturbances introduced by LFC devices such as suction holes, e.g., Tollmien–Schlichting (TS) waves. In particular, the objective is to identify the conditions under which the interactions are favorable (e.g., suppression of TS wave growth) or detrimental (e.g., secondary instabilities associated with the vortices).

Progress and results

Previous measurements had indicated the presence of weak streamwise vortices in the boundary layer. The vortices originate at the leading edge and appear to be caused by almost immeasurably small nonuniformities in the free stream. At the outset, the plan was to first improve the flow quality of the free stream. Following the general approach used in transition experiments, the disturbances of interest could then be introduced in a controlled manner. The flow quality improvements were much more difficult than anticipated; more than half the project time (and funding) was required to establish a very-high-quality base flow, i.e., as free as possible of background disturbances.

Klebanoff modes are thought to originate from disturbances generated by the wind tunnel screens. Inspection of the old wind tunnel screens revealed that the tension was quite low and nonuniform. Six new, high-quality screens were attached to solid aluminum screen frames as a replacement set. A special effort was made to achieve a high and uniform tension of the screen cloth. Hot-wire measurements were made for both sets of screens in a spanwise plane (x = 1 m, $\mathrm{Re}_x = 1.25 \times 10^6$). Flow quality is commonly quantified by the root mean square (rms) unsteadiness and the uniformity of the free stream. These measurements indicated almost no change after replacing the old screens [rms free-stream velocity fluctuation (u_{rms})/mean free-stream velocity (U_∞) = 0.08%]. However, the maximum amplitude of the Klebanoff modes within the layer was found to be reduced by a factor of three. Despite the overall improvement in flow quality, centerline mean velocity and broadband unsteadiness profiles indicated that intermittent bursting occurred at x =1.2 m ($\mathrm{Re}_x = 1.50 \times 10^6$). This observation is very interesting since intermittent bursting with the old screens was found to occur at x = 1.8 m ($\mathrm{Re}_x = 2.25 \times 10^6$), i.e., the Reynolds number for the onset of transition with the new screens was reduced by 50 percent.

Wool tuft visualization studies within the original wind tunnel fan revealed that flow separation occurs within the casing. Further, viewing the wool tufts with a stroboscopic light source revealed that the separation is highly unsteady and it appeared to be correlated with the angular position of the blades with respect to the outlet. Hot-wire spectral measurements in the test section indicate that up to 50 percent of the total free-stream unsteadiness occurs within a narrow band surrounding the blade-passing frequency. This frequency coincides with the most unstable TS modes. The seemingly anomalous behavior (i.e., improved flow quality but earlier transition) can be explained by noting that larger amplitude Klebanoff modes were present in the layer with the old screens. The reduced magnitude of the Klebanoff modes with the new screens allowed the blade-passing-induced TS

components to grow to a large enough amplitude to cause bursting.

Considerable time was spent altering the pressure/flow-rate requirements of the original fan in an attempt to reduce the size and frequency of the blade-induced disturbances. However, none of these tests was successful and it was concluded that the existing centrifugal fan must be replaced with a high-flow quality axial fan before the measurements could proceed.

A new axial flow fan that required substantial tunnel modifications was identified and purchased. The combination of the new fan and the six new screens restored the Reynolds number for the onset of bursting to the previously observed value and led to a factor of 10 reduction in the amplitude of the background rms disturbance levels. However, substantial spanwise variations still existed within the layer. Accordingly, 6 more screens were manufactured and added to the tunnel configuration. Furthermore, the quality of all 12 screens was determined by laser scanning. This technique involved mounting the screen on linear bearings such that the screen cloth passed between a laser and a photo detector. The laser beam diameter (approximately 0.1 inch) corresponds to about 4 mesh widths, i.e., the laser light passed through approximately 16 mesh openings. The variations in the photo correspond to variations in the mesh size, which introduce the small nonuniformities in the free stream. The order of screens in the tunnel was based on these mesh uniformity measurements, i.e., from worst to best in the flow direction. Although this led to further improvements, concentrated regions of elevated background rms levels remained. Finally, it was discovered by experiment that the appearance of these regions was sensitive to pressure gradients in the vicinity of the leading edge. The remaining concentrated regions were removed by imposing a small favorable pressure gradient in the vicinity of the leading edge by means of a contoured ceiling. The net result was a reduction in the rms background unsteadiness within the layer by a factor of 50.

A pair of streamwise vortices were introduced into the boundary layer in a controlled manner by stretching a 0.001-inch-diameter wire across the flow in the direction normal to the leading edge 6750 diameters upstream. The laminar wake behind the fine wire leads to the formation of a pair of streamwise vortices within the layer. The strength of the vortices can be controlled by varying the wire diameter and its distance from the leading edge. The spanwise position of the vortices is adjusted simply by moving the wire to a different spanwise position. The vortices represent the controlled background disturbance.

A disturbance representative of LFC devices is the harmonic point source (HPS). The HPS was introduced via a small speaker attached to a tube to a pressure tap on the centerline of the test plate. One of the characteristics of HPS-generated TS waves is that the maximum rms amplitude downstream of the source occurs away from the centerline. As the waves fan out in the spanwise direction, they interact with the streamwise vortices generated by the wire. The HPS TS waves have been measured with and without the presence of the wire-induced vortices.

Results to date have indicated that the interactions are more complicated than anticipated. Examples have been discovered where the presence of the vortices both increase and decrease the amplitude of the TS waves. This work is continuing under conventional funding.

Significance of the results

The results demonstrate the importance of accounting for nonlinear interactions for the accurate prediction of transition. Nonlinear interactions will occur in practical flows of interest (e.g., airplane wings) but conventional computational tools cannot account for them. The measurements will be put in the form of a database for validation of advanced computational codes.

The unanticipated difficulties with obtaining sufficiently high flow quality are relevant to large-production wind tunnels. An extremely high flow quality will be required for testing models containing LFC devices. Furthermore, the techniques that are generally accepted to quantify flow quality were inadequate for flow improvements.

Publications resulting from study

Watmuff, J. H.: Interactions between Klebanoff Modes and TS Waves. Paper presented at DFD meeting, Amer. Phys. Soc., Syracuse, N.Y., Nov. 24–26, 1996.

Watmuff, J. H.: Interactions between Klebanoff Modes and TS Waves in a Blasius Boundary Layer. AIAA Paper 97-0558, presented at 35th AIAA Aerospace Sciences Meeting and Exhibit, January 6–9, Reno, Nev., 1997a.

Watmuff, J. H.: Detrimental Effects of Almost Immeasurably Small Free-Stream Nonuniformities Generated by Wind Tunnel Screens. AIAA Paper 97-0228, presented at 35th AIAA Aerospace Sciences Meeting and Exhibit, January 6–9, Reno, Nev., 1997b.

Keywords

Flow quality, Klebanoff modes, Tollmien–Schlichting waves

Ground-Based Photometric Detection of Terrestrial-Sized Extrasolar Planets

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Objectives of the study
The detection of extrasolar planets remains a difficult task; the results of reference 1 in the detection of Jovian-mass planets required a ten-year program using three-meter-class telescopes. (Reference 1 reports measurements of periodic velocity shifts in the spectral lines of solar-type stars, which are indicative of a perturbing mass.) This method is the only one that has unambiguously yielded extrasolar planets around solar-type stars. (Planetary masses have been detected around two pulsars; see refs. 2 and 3.) Of interest, of course, in light of NASA's stated goal of detecting habitable extrasolar planets, are planets smaller than Neptune (i.e., terrestrial-sized), a feat considered impossible from the ground because of atmospheric scintillation effects. However, as pointed out in reference 4 and demonstrated in reference 5, the detection of nearby Earth-sized extrasolar planets from the ground around very small eclipsing binary stars is possible using one-meter-class telescopes with moderately good photometric precision.

The photometric method relies on the transit of an extrasolar planet across the line-of-sight of a star; periodic brightness changes, which must be separated from star spots, intrinsic stellar variability, and so on, are measured. However, the probability of a transit across the line-of-sight is only about one percent (ref. 6), for random orientations of the planetary orbital plane to the observer, so that one is faced with either somehow preselecting edge-on systems (the method used in this project) or one must look at about 100,000 stellar systems so that statistically at least some will be edge-on (the approach planned for ref. 7).

Progress and results
Small eclipsing binary systems were selected for this project for four major reasons (starting with the smallest known eclipsing binary, CM Draconis):

1) The orbital plane of eclipsing binary systems is already edge-on, and a protoplanetary disk forming around it should cause material to precess into this plane (material at different distances around the binary stars will precess at different rates because of the binary mass distribution, thereby collisionally dampening into the binary orbital plane; ref. 4). Thus, accreting planets should form in a plane parallel with the binary system orbital plane and thereby parallel to the same line-of-sight for eclipsing systems.
2) Small systems are chosen because the smaller the system, the larger will be the differential brightness variation because of the transit of a planet. CM Draconis, for example, has a total stellar disk area (of both components) only about 12 percent that of the sun, allowing almost an order-of-magnitude smaller planets to be detected for a given photometric precision.
3) Assuming that the thermal regime of the solar system correlates with the condensation locale of the planets, the low intrinsic luminosity of these small systems should cause planetary bodies to form significantly closer to the stars than in our solar system. For example, a planet with an insolation (stellar flux) equivalent to that received by Earth around CM Draconis would have a period

of about 19 days. Hence, detection of inner planets should take on the order of weeks rather than years.

4) The phase position of the binary stars (zero phase is at primary stellar eclipse) makes the transit of any planets quasiperiodic, that is, even a planet in a circular orbit will transit the stars in a different way each orbit since the binary components will also be orbiting around each other. This quasi-periodic signature is actually helpful. Cross-correlating the observed brightness variations with a model of all possible transit configurations (a matched-filter approach) will provide a transit signature well below the noise to be detected (ref. 5).

The main thrust of this work (and the most observing) is dedicated to the detection of terrestrial-sized planetary systems. To date, the stellar system CM Draconis has been observed for almost 1000 hours for evidence of terrestrial-sized planetary transits. At the current stage of data analysis, 19 candidate transit events have been found, with some periods fitting 5 transits in succession. The transit detection algorithm (TDA, a crosscorrelating matched filter) will soon be run on the whole data set. Any planets with periods of 60 days or less will thereby either be ruled out around this system or any that are 1.8 Earth radii or larger will be detected (this planetary size minimum is about 0.6 percent the size of Jupiter.) Thus, a beginning will have been made at finding habitable-sized planets.

As a byproduct of this effort, a method has been found to detect nontransiting giant planets around small-mass eclipsing binaries using the binary system as a clock (ref. 8). As the two stars orbit each other, the mutual eclipse minima can be measured precisely using Global Positioning System (GPS) timing signals. If there is a giant planet in orbit around the binary, the stellar system will be displaced periodically by the motion of that giant planet about the barycenter. This offset will cause a delay of several seconds in the smallest mass eclipsing binaries for a Jupiter-mass planet at a Jovian distance from the stars. By precisely timing the eclipses, any periodic offset can be measured or giant planets can be ruled out if no timing offset is detected. We should be able to constrain the existence of giant planets around eleven stellar systems by the end of this year's observing season.

Significance of the results

Although there are indications for the existence of a planet in CM Draconis, the data are still tentative and will require further analysis. A positive result will underscore the importance of photometric observations for the detection of planetary systems and the feasibility of detecting Earth-sized planets from space where the photometric precision is not limited by the atmosphere. This seed funding has been invaluable in allowing development of these techniques and making progress with observation of these systems. Given recent discoveries, it is clear that progress in the search for extrasolar planets requires much more observation than theory.

Publications resulting from study

Doyle, L. R.; Dunham, E. T.; Deeg, H-J.; Blue, J. E.; and Jenkins, J. M.: Ground-Based Detectability of Terrestrial and Jovian Extrasolar Planets: Observations of CM Draconis at Lick Observatory. J.G.R.-Planets, vol. 101, no. E6, pp. 14823–14829.

Doyle, L. R.; Jenkins, J. M.; Deeg, H-J.; Martin, E.; Schneider, J.; Chevreton, M.; Paleologou, E.; Papamastorakis, J.; Lee, W-B.; Kim, H-I.; Dunham, E.; Blue, E.; and Toublanc, D.: Observations to Detect Planets Around Eclipsing Binary Systems. Bull. Am. Astron. Soc., vol. 27, 1995, p. 1382.

Doyle, L. R.; Jenkins, J. M.; Deeg, H-J.; Martin, E.; Schneider, J.; Chevreton, M.; Paleologou, E.; Kylafis, N.; Lee, W-B.; Dunham, E.; Koch, D.; Blue, E.; Toublanc, D.; Ninkov, Z.; and Sterken, C.: Ground-Based Observations to Detect Terrestrial and Jovian Planets around CM Draconis. Bull. Am. Astron. Soc., vol. 27, 1995, p. 105.

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Keywords
Planet detection, Eclipsing binaries, Extra-solar planets

Development of an Innovative Neural-Based Telescope Balancing System for the SOFIA/Kuiper Airborne Observatory

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Objectives of the study
To develop an innovative, noncontacting method for neural-based telescope balancing. Such a system will improve the efficiency of the balancing task; achieve precise balance; eliminate dependence on expert skills; and improve onboard compensation of mass changes, cabling loading, and aerodynamic loads.

To demonstrate the feasibility of such a system, a 1/2-scale hardware model of the Kuiper Airborne Observatory (KAO) telescope will be used, and then the actual KAO telescope itself will be used.

Progress and results
During the previous fiscal year, the instrumentation concept was finalized, the key equipment (including noncontacting infrared sensors, data acquisition boards, portable computer, and graphics software) was procured; the feasibility of using the noncontacting sensor onboard the KAO telescope to accurately measure imbalance motions was determined; a simple hardware testbed was built for initial neural net training and experimentation (fig. 1); a three-dimensional (3-D) stereographics dynamics model of the KAO telescope was developed for further experimentation (fig. 2); a 1/2-scale hardware prototype of the KAO telescope was built; and various neural-based balancing methodologies were investigated.

During FY96, the 1/2-scale KAO telescope prototype testbed was completed, neural-based experiments were conducted using this testbed, enhancements to the testbed were implemented, and complementary neural-based approaches for telescope balancing were developed.

The general methodology developed is as follows: An innovative, noninvasive infrared detector is used to measure the trajectories generated by known weights at known locations. The data collected are used to train neural networks to learn the inverse transfer function. Once trained, the neural networks are used to determine the counterweight balance parameters from new trajectory data caused by an imbalance.

Experimental results indicate that the proposed use of an innovative, noninvasive infrared detector to measure motion trajectories caused by imbalances is feasible; that the motion trajectories are uniquely caused by mass imbalances; that nonlinear effects can be mainly attributed to loading from wire harnesses and to air-bearing drag; and that an accurate inverse transfer function can be learned and then utilized to determine counterweight parameters using neural net algorithms. In addition, a cost-effective alternative to the expensive spherical air bearing has been developed that can be used for offline, preflight balancing of the telescope.

Significance of the results
The current method for balancing the Kuiper telescope is based on a difficult, time-consuming trial-and-error procedure that can take up to four hours. An automated approach is needed to

1) improve efficiency of time to balance;
2) improve accuracy of imbalance compensation;
3) eliminate dependence on expert skills; and
4) improve onboard balancing of mass changes (due to cryogenic boil-off) and aerodynamic loading effects.

A method has been developed for balancing the Stratospheric Observatory for Infrared Astronomy (SOFIA)/KAO telescopes accurately and efficiently. The hardware requirement on the telescope is simply a small, 1/4-inch-diameter reflector. The neural-based procedural method for balancing will reduce operating cost, allow technicians at any level to perform the task, and reduce the time to achieve precise balance. As mentioned previously, an inexpensive alternative to spherical air bearing that can provide a high-fidelity, ground-based simulation of an expensive air bearing for the balancing task is now available. Finally, the innovative contacting method developed

here has great potential for enabling adaptive online balancing for compensating for mass changes, cable loading/stiffness changes, and aerodynamic loads.

Keywords
Neural networks, Telescope balancing, SOFIA telescope

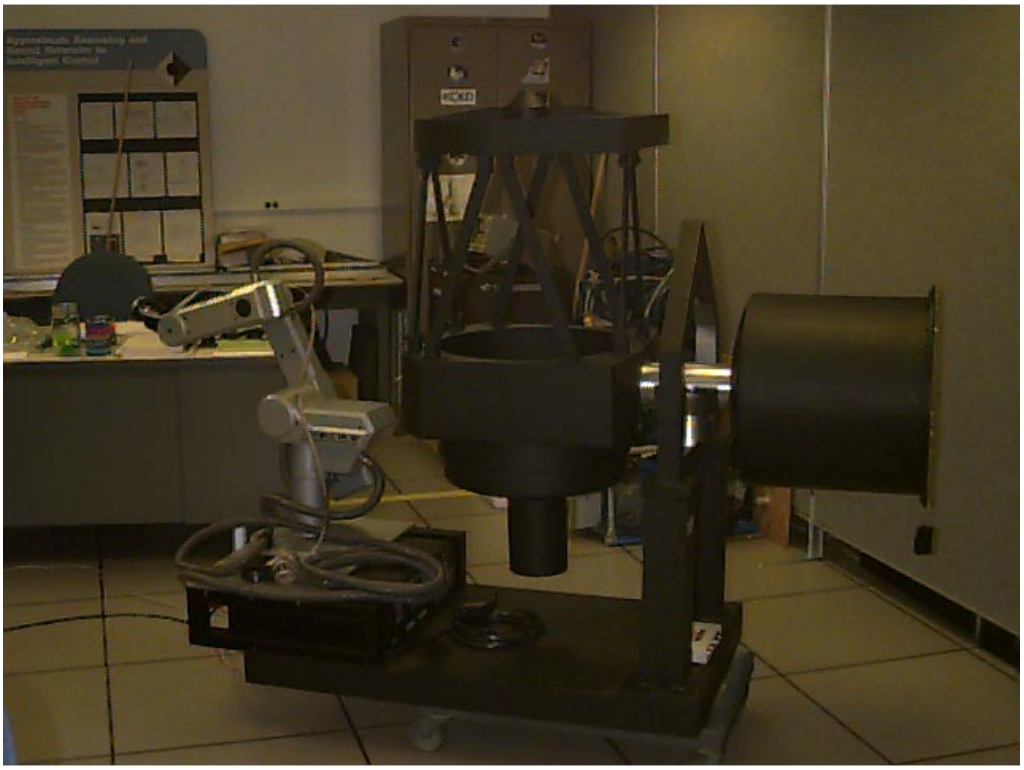

Figure 1. SOFIA/KAO telescope hardware testbed.

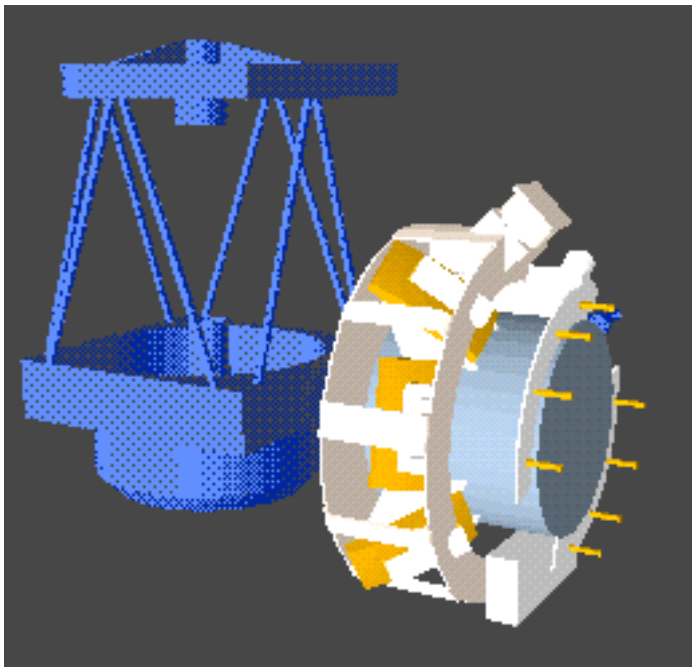

Figure 2. KAO/SOFIA telescope; 3-D stereographic dynamics model testbed.

A Microwave-Pumped Far Infrared Photoconductor

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Objectives of the study

The far infrared (IR) response of a high purity *n*-GaAs photoconductor is characterized by excited state transitions of the residual shallow level impurities superimposed on a relatively broadband continuum. The response covers the range of 35–100 cm^{-1} with a dominant peak, belonging to the 1s–2p transition, at about 35.4 cm^{-1} (279 μm). The exact excited state response is sample dependent since the concentration of the different impurity species depends on the preparation and growth methods and conditions. The liquid-phase epitaxy has proved to be the most successful growth method in terms of producing the highest purity material.

The underlying theory of operation of this detector is almost perfectly explained in terms of a simple hydrogenic model (fig. 1). The detection mechanism for this detector is photothermal ionization, a two-step process where the ground-state electrons absorb far-infrared radiation to reach the excited state levels and then they are thermally ionized to the conduction band. Although thermal ionization is the most convenient way to complete the transition to the conduction band, it is conceivable that alternative methods, such as photoionization by microwave photons, can be employed to induce such a transition. The ground-state thermal ionization energy for all donor impurities is approximately the same and is about 5.5 meV. As the purity of the material decreases, the thermal ionization energy decreases as well. For this reason, far infrared photoconductivity is observable only in high-purity material or at very low temperatures.

Dark current was measured as a function of temperature. Under the dark condition, the blackbody was turned off and the detector was looking at the ambient temperature. It is interesting to note that the dark current drops more rapidly at higher temperatures. This fact is illustrated in figure 2, where the dark current at 300 mV bias is plotted as a function of temperature. The excessive dark current at the higher temperatures generates excess noise, which dramatically lowers the detectivity of the photoconductor. Thus operation at a temperature of T = 2 K or less is desirable for noise purposes.

The spectral response of the detector was measured as a function of temperature and bias using the Bomem Fourier transform spectroscopy (FTS) (fig. 3). For these measurements a cold black polyethylene and a cold scatter filter (diamond powder on quartz) were used to reject the high-frequency radiation. The raw spectra were corrected for the FTS source and optics by dividing them by the background spectrum. The background was taken under identical conditions using a bolometer. Since the bolometer is a thermal detector, its spectrum was divided by the frequency. Considering that photothermal ionization is the primary detection mechanism, one would expect the strength of the exited state response relative to the continuum response to diminish with decreasing temperature but to remain constant with changing bias. Of course the overall response would change with both temperature and bias because of the change in mobility. The results agreed with the expectations and, therefore, confirmed the photothermal ionization process. Response at the desired peak decreases exponentially with temperature according to a Boltzmann factor, and is down by two orders of magnitude at a temperature of T = 2 K (fig. 4). This result makes the detector's responsivity very low at cold operating temperatures.

The objectives of the study were to ascertain the feasibility of microwave-pumping, the second step of the ionization process in a cold T = 2 K detector. This feasibility would eliminate the need for the T = 4.2 K high temperatures required for thermal ionization, and would eliminate the associated high dark currents. Such an improvement would allow operation of the detector at full peak responsivity, as at T = 4.2 K, but with the much lowered thermal leakage current present at T = 2 K. This improvement can be viewed either as a reduced noise for a full spectral range detector that is run colder or as increased spectral range for a cold detector when pumped by microwaves.

Progress and results

Realization of the goals of this study required development of expertise in the area of microwave technology. The most difficult aspect was in coupling the microwave power appropriately into the GaAs detector itself, while maintaining DC bias and IR illumination (fig. 5). Additionally, procurement of specially produced and optimized microwave sources, couplers, tuning cavities, and antennas were required,

delaying progress. First-ever measurements of microwave postpumping of states excited by far (35.4 cm^{-1}) IR radiation were made. The success of this method can lead in the future to higher energy photon pumping (by millimeter waves) of shorter wavelength detectors such as Ge and Si.

The main effects to be observed from successful microwave pumping are an increase in photocurrent and a change in the relative spectral response shape at a given bias and at low temperature (T < 3 K). These changes should be dependent on the power (and possibly frequency, which has not yet been explored) of the microwave energy impinging on the detector. The following data in support of these effects have been observed: the photocurrent increases with the microwave source on, and decreases to normal with it off, in a repeatable manner; and the effect of the tuning slug on the microwave cavity, which couples the energy to a fixed-position antenna rod, is to cause the photocurrent to vary up and down sinusoidally with position when the microwaves are on. Both of these effects are good evidence of the proper and expected interaction between the microwave source and the excited state response of the IR photoconductor.
The definitive proof of the proper interaction with the excited state response would be to observe the spectral line shape change, from that of a T = 2 K shape to one similar to that seen at T = 4.2 K (fig. 2) when pumping a T = 2 K detector with microwave energy. This observation requires use of an FTS system such as that used to acquire the data of figures 2 and 3. Unfortunately, the present Ames system is under repair and is not presently available to take these data. When the spectrometer is working, however, verification that the effects discussed are definitively due to microwave postpumping of the detected electrons out of the excited state into the conduction band will be made. This last piece of proof will allow us to publish results.

Significance of the results

Postpumping of IR photoconductors could allow the entire array of existing extrinsically doped devices to cover a broader spectral range with little or no noise increase and low pumping power requirements, eliminating the need to find new detector materials or device structures in some cases, and eliminating such hard-to-implement technologies as stress rigs for detector arrays.

Publications resulting from study

Farhoomand, J.; McMurray, R. E., Jr.; Haller, E.; Bauser, E.; and Silier, I.: Characterization of High Purity GaAs Far-Infrared Photoconductors. International J. Infrared and Millimeter Waves, vol. 16, no. 6, 1995, pp. 1051–1064.

Keywords

Photoconductors, Detectors, Infrared

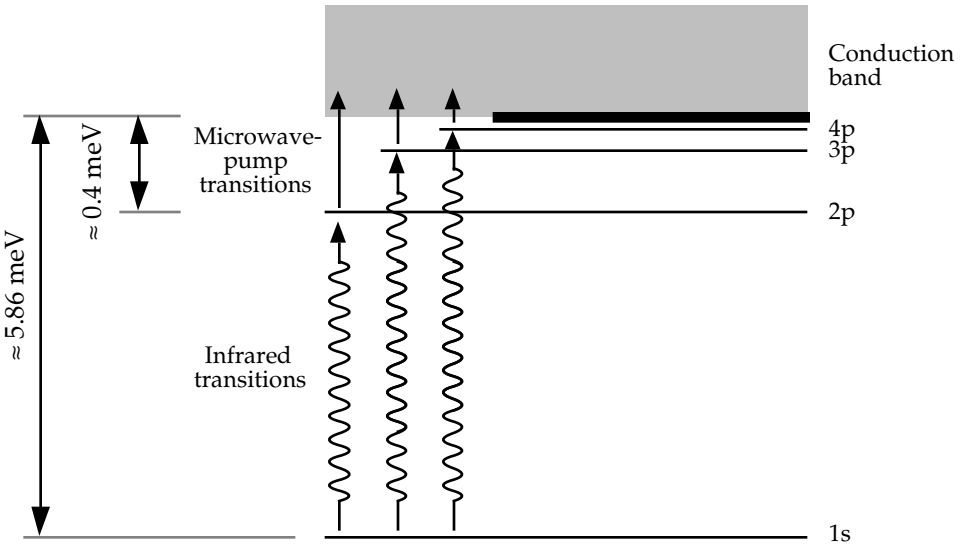

Figure 1. Energy-level diagram of shallow donors in GaAs (not to scale).

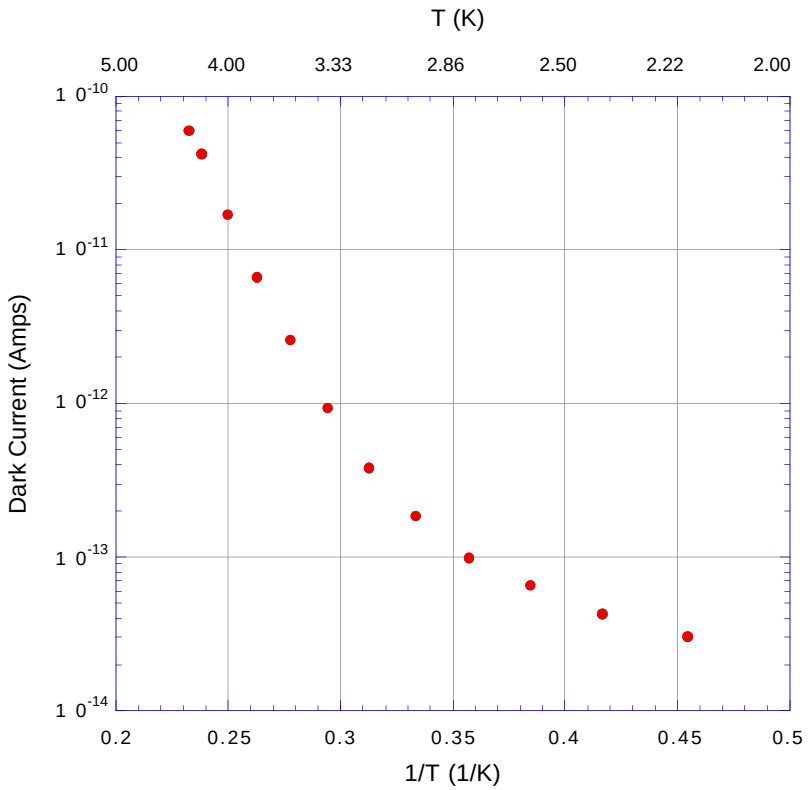

Figure 2. DC dark current at 300 mV vs. temperature.

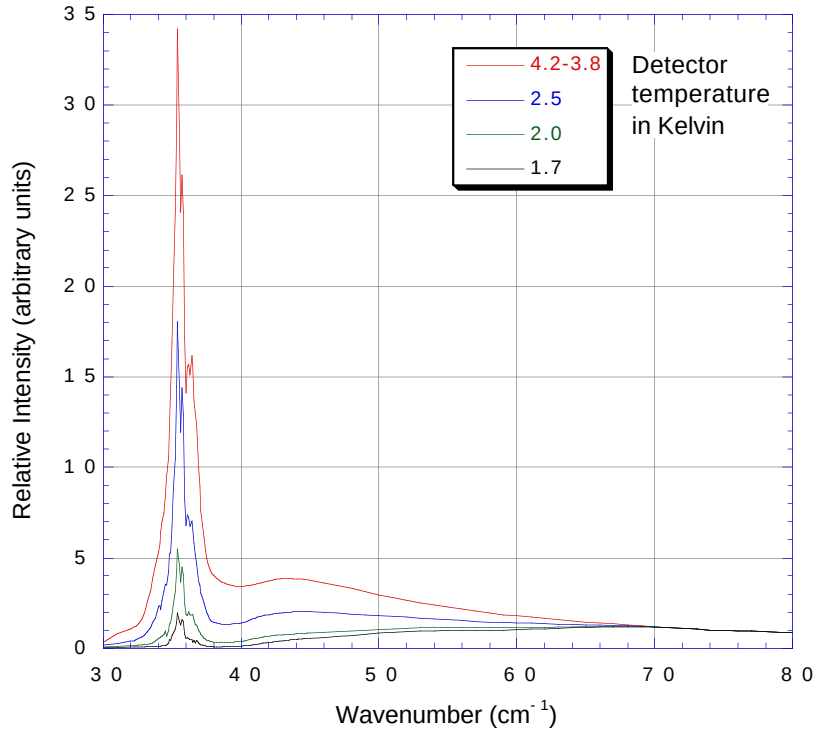

Figure 3. GaAs spectral response vs. temperature normalized to the continuum response at 80 cm^{-1}.

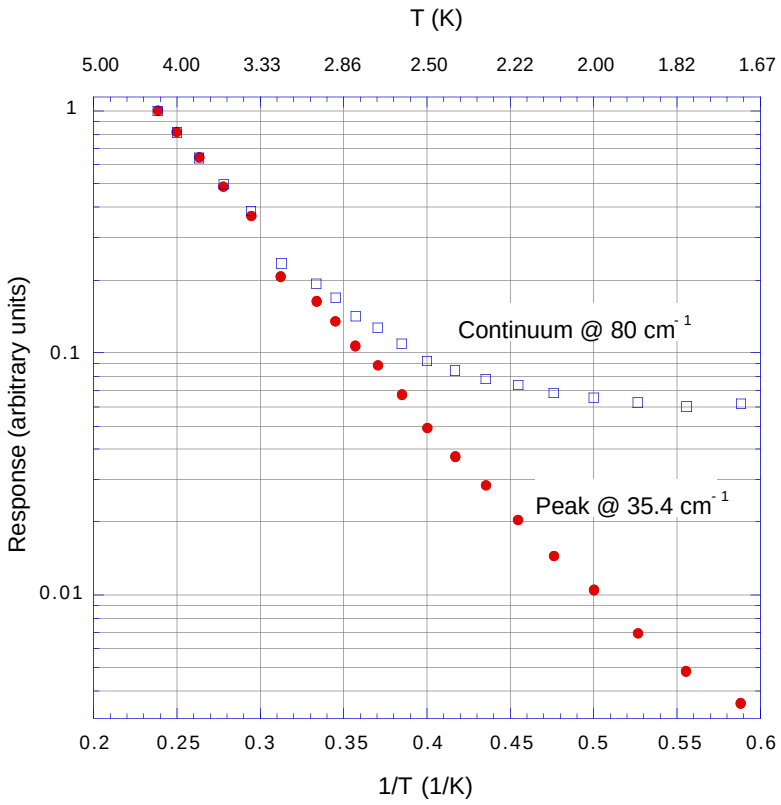

Figure 4. GaAs response at 35.4 cm^{-1} and at 80 cm^{-1} vs. temperature, both normalized to the response at 4.2 K.

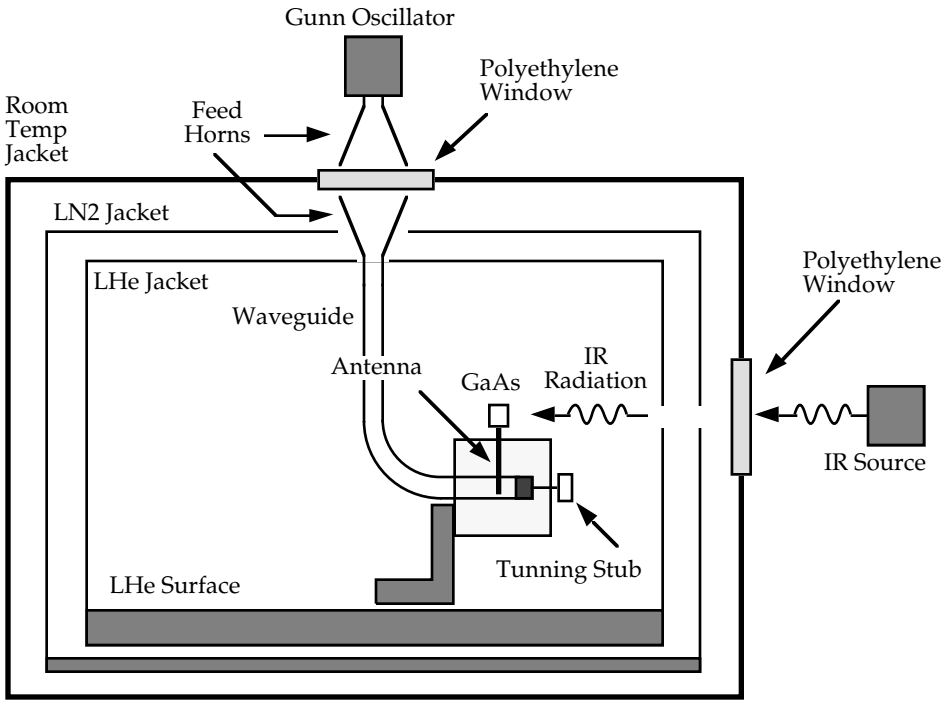

Figure 5. Optical diagram of the microwave-pumped GaAs photoconductor.

A Search Technique for Discovering Earth-Crossing Comets from Meteor Stream Outbursts and Determining their Orbits in Space

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Other personnel involved
Amateur astronomers have participated at various stages in this project. A multistation photographic network was employed in the California Bay Area during the 1994 Leonids, the 1994 Ursids, the 1995 Perseids, the 1995 Aurigids, the 1995 Leonids, and the 1996 Perseids. Members of the Fremont Peak Observatory Association and the San Jose Astronomical Association (Mike Koop, R. Morales, C. Angelo, T. Rice, and others) participated. In Hawaii during the 1995 Lyrids, members of the Meteor Group Hawaii (Mike Morrow and others) participated. Members of the Meteor Section of the South African A.S.S.A. (T. Cooper and others) participated in South Africa during the 1995 kappa-Pavonids. In Brazil during the 1996 kappa-Pavonids, a group of people associated with the Planetarium of Porto Alegre (G. Klar Renner and others) participated, while in Spain during the 1995 alpha-Monocerotids, members of the Dutch Meteor Society (H. Betlem, M. de Lignie, and M. Langbroek and others) and SOMYCE, the Spanish Meteor Society (L. Bellot and others) participated. At the alpha-Monocerotids occasion a two-station network of image-intensified video cameras was employed.

H. Betlem and H. Mostert developed the photographic systems, while M. de Lignie and K. Jobse developed the image-intensified video camera systems. I. Yrjölä designed the current radio meteor scatter system.

Objectives of the study
To develop techniques and gain information that would allow us to find Earth-threatening long- and intermediate-period comets through their meteoric signatures. Before this study, only anecdotal accounts of meteor outbursts existed, brief enhancements of meteor rates, which are a signature of comets in an orbit that closely approaches the Earth's orbit. No such event had been observed with modern meteor observing techniques. Results of this study demonstrate that it is possible to measure orbital elements of outburst meteoroids and, from that information, to determine the orbit of the parent comet.

Progress and results
The level of normal annual activity of 49 meteor streams from which meteor outbursts stand out was determined. An inventory of historic accounts of meteor outbursts revealed that there are two types of meteor outbursts: near-comet type, which are associated with the return of the comet to perihelion, and far-comet type, which are not. Photographic and image-intensified video techniques were developed into mobile systems suited for application to this study and the possibilities of radio forward meteor scatter for detecting yet-unknown streams were explored. The first orbital elements of a near-comet type event, which originate from a known intermediate-period comet (P/Swift-Tuttle), were secured.

Results indicating that the occurrence of far-comet outbursts correlates with the Sun's reflex motion (ref. 1) allowed prediction of such an event for November 22, 1995, between 0 and 6h Universal Time (UT). (See ref. 2.) This outburst of alpha-Monocerotids did indeed occur, peaking at five meteors per minute at 01:29 UT that night. Three photographic and seven video orbits of these meteoroids were secured. From that, the approximate orbit of the parent comet was derived, and from the dispersion in orbital elements and the intensity and duration of the outburst, the size of the object was estimated. Observations established that this event was caused by an Earth-threatening long-period comet (ref. 3).

Results were presented at the international symposium Physics, Chemistry and Dynamics of Interplanetary Dust, IAU Coll. 150 in Gainesville, Fla. (Aug 1995) and at the symposium Asteroids Comets Meteors 1996, in Versailles, France (July 1996). Popular presentations were given at Fremont Peak Observatory, Calif. (Nov. 1994, Feb. 1996), in Johannesburg, South Africa (July 1995), at the Planetarium of Porto Alegre, Brazil (July 1996), and for the Dutch Meteor Society in Rotterdam, The Netherlands (June 1996).

Significance of the results
Demonstration that it is possible to observe meteor outbursts and measure orbital elements of the

meteoroids enables mounting other such observing campaigns for streams that are known to have occasional far-comet type outbursts, and thus determining the orbits of other Earth-threatening comets.

Results established that yet-unknown streams can be detected by radio forward meteor scatter and visual observing techniques. Once observed, it is possible to predict future returns and mount an observing campaign to measure the orbital elements. Once the approximate orbit has been determined and the size of the parent object has been estimated, it is possible to search for near-Earth objects in that part of the orbit that would bring the object on a direct collision course with Earth. That capability can significantly increase the warning time necessary for avoiding potential danger.

The necessary information to secure funding for a continuation of this project aimed at finding all Earth-threatening, long-period comets that can be discovered in this way has been obtained. A proposal has been submitted to NASA's Planetary Astronomy Program.

Publications resulting from study

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Jenniskens, P.; and van Leeuwen, G. Docters: The Alpha-Monocerotid Meteor Outburst: the Cross Section of a Comet Dust Trail. Submitted to Planetary Space Science, 1996.

Yrjölä, I.; and Jenniskens, P.: Meteor Stream Activity. V. A Survey of Annual Meteor Activity by Means of Forward Meteor Scatter. Submitted to Astron. and Astrophys., 1996.

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3. Jenniskens, P.; Betlem, H.; de Lignie, M.; and Langbroek, M.: The Detection of a Dust Trail in the Orbit of an Earth-Threatening Long Period Comet. Astrophysical J., 1996 (Feb. 1997 issue—in press).

Using Ecosystem Science and Technology to Balance the Conservation of Water Supply and Native Hawaiian Forests

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Objectives of the study
Maui's native rainforests are among the most imperiled in the world, containing one-third of Hawaii's rare and endangered species. Research has shown that native species are highly susceptible to displacement by the invasion of nonnative species. Alien species have been shown to affect ecosystem function, community structure, and population dynamics (ref. 1). The mission of the East Maui Watershed Partnership (EMWP) is to protect the East Maui watershed from degradation by pooling expertise and other resources to plan, fund, and implement an active watershed management program.

With the cooperation of the State of Hawaii and the Nature Conservancy of Hawaii, a multiscale study of the spread of alien plant species into the native rainforests of windward East Maui is being conducted. The East Maui watershed is managed by seven land owners, who formed the EMWP. The research focuses on two priorities from the EMWP management plan, which was based on recommendations made by the U.S. Forest Service: 1) Determine the specific steps needed to develop an adequate inventory of vegetation and species in the watershed in order to provide a starting point for ongoing and long-term monitoring; 2) Provide a strategy to prevent new weeds from entering the watershed area and target those species that pose the greatest threat to native species. The EMWP understands that at the heart of the watershed are the native rainforest ecosystems, which support a host of native and endemic species and form the basis of the present and future water supply for the island of Maui.

The research focused on the following questions: 1) Is the presence and extent of alien species related to land use (including natural or human disturbances and preservation)? 2) Can canopy cover interpreted from historic aerial photos be used to identify species change (alien species spread) in native forest? and 3) At what spatial scale is the change in canopy species composition most obvious?

Previous research has suggested that the presence and extent of alien species are related to disturbance, whether the result of human land use or natural events. The first goal was to identify areas where aliens are posing the most immediate threat of spread into native areas, and the possible relationship to management policy and other landscape variables. A gap analysis of the macroscale data was analyzed in the geographic information system (GIS) software ARC/INFO, comparing agency land-use policies with the presence of native and alien vegetation cover to identify gaps in protection of native forest. The second goal was to show how the vegetation canopy structure has changed over time, in particular, the change in the percent of alien and native species. The third goal was to identify what landscape features and species assemblage information can be detected at each scale. The abilities and limitations of the three scales of observation to detect landscape features and vegetation patterns were compared and analyzed.

Progress and results
A landscape ecology approach was employed using historical literature and current technology to evaluate vegetation changes over time in the East Maui watershed ecosystem. The work had three components: a gap analysis, which looked for "gaps" in the protection of native plant and animal species based on the type of conservation management; a complete historical review of land use and vegetation change back to the arrival of the Polynesians, including a 40-year time sequence of historical aerial photos; and a comparative multiscale analysis of four scales of vegetation data: satellite remote sensing, aircraft remote sensing, aerial photography, and ground transects and permanent plots to determine the most cost-effective and efficient tool for long-term monitoring of the watershed.

Preliminary results of this work suggest that a multiscale approach, using ground-based transect monitoring, aerial photography, and remote sensing combined in an ARC/INFO GIS is a viable way to study land-use and land-cover change. Most of the native plant and animal species occur in areas managed for multiple use and are, therefore, at risk without a focused monitoring and management plan.

The historical review of land-use change indicated that most of the changes to rainforest habitat, and the consequent loss of species, occurred first with the arrival of the Polynesians about 400 A.D. and continued with the arrival of the Europeans after 1778 and on through today since the advent of sugarcane production at the turn of the century. In East Maui, it was not until the mid 1800s when sugarcane was developed as an industry, that roads into East Maui were built and irrigation ditches were built to bring water from the watershed to agricultural lands. Alien plant and animal species introduced at each of these three times have replaced the native vegetation in the lower elevations, and are encroaching on it mauka (inland, toward the mountains).

Preliminary results of the multiscale analysis indicate that, for detailed habitat inventory, the ground-based transect method provides the greatest detail, although at great expense, and for a very limited area. Aerial photo reconnaissance provides both the history and more canopy detail, but depends highly on the knowledge of an interpreter to locate specific species of special concern. It, too, is labor intensive and expensive to include the data in a GIS for display and analysis.

Aerial photos from the 1995 NASA C-130 for the Koolau Gap–Keanae Valley area were digitized, orthorectified, and mosaicked into a single photo-map. This photo mosaic map was then included in the East Maui GIS database.

Significance of the results

The data collected in this research are being intgrated with the ground data collected in Hawaii by The Nature Conservancy of Hawaii. Linked together by the Global Positioning System (GPS) location in the Environmental Systems Research Institute, Inc.'s (ESRI's) ARC/INFO GIS, a resource manager or researcher can point the cursor to any point along Transect 4 and bring up information about that particular spot on the ground on soils, birds, endangered plants, endangered animals, vegetation cover, weed species present, and signs of feral ungulates. These data can also be overlaid on a shaded relief map, elevation contours, the 1995 aerial photo mosaic, the 1995 thematic mapper simulator (TMS) data image, the SPOT remote sensing satellite image, or the transverse magnetic (TM) image. In the area of highest vegetation transition (from about 1500 to 3500 feet), comparisons can be made with the historic aerial photography dating back to 1951. This capability allows for more detailed analysis of the data and interactions among living and nonliving systems. These data will be analyzed and reviewed for many years to come. The final report (in press October 1996) provides recommendations for future ground and aerial monitoring efforts in the East Maui watershed.

Publications resulting from study

Numerous publications have resulted from this research; they are available on the World Wide Web at http://ice.ucdavis.edu/~robyn/curvitae.html.

References

1. Vitousek, P. M.: The Effects of Alien Plants on Native Ecosystems. In Alien Plant Invasions in Native Ecosystems of Hawaii: Management and Research, C. P. Stone, C. W. Smith, and J. T. Tunison, eds., U. Hawaii Press, Honolulu, Hawaii, 1993.

Keywords

Watershed, Geographic information system, GIS, Landscape ecology, Remote sensing, Ecosystem, Management, Hawaii, Aerial photography, Maui

A New Method for Measuring Cloud Liquid Water Using Near Infrared Remote Sensing

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Objectives of the study
To develop cloud remote sensing methods for inferring the liquid water content (LWC) of clouds, which includes the subsequent development of experimental [a solar spectral flux radiometer (SSFR)] and theoretical tools necessary for cloud property retrievals. Because the LWC in clouds is so crucial in the regulation of the Earth's hydrological cycle and therefore has direct climate implications, and because cloud water content has been so poorly sampled because of its dependence on temperature, this effort to use a near infrared (NIR) remote sensing technique was initiated. Measurements of NIR scattered by clouds have been used in past studies to infer cloud properties such as particle size, cloud thickness, and thermodynamic phase of cloud water, with varying degrees of success. The objectives of this study are to use a similar approach in determining cloud water content by measuring the NIR solar spectrum transmitted through clouds and deriving the relationship between the spectral information and cloud water content.

Progress and results
Analysis of Arizona Program data continued. A new method of analyzing surface-base cloud transmission spectra, developed during the first year of this project, was useful in deriving both cloud liquid water and water vapor. Presently, the retrieval method derives the relative proportions of those quantities. New analysis, based on photon path length distribution calculations, will be necessary to obtain liquid water and water vapor in absolute units. Nevertheless, the work completed during the two years of this project went far in developing this new remote sensing technique. Furthermore, the instrument developed for this study, and the data acquired during two major field campaigns, was applied to other current problems in solar radiative transfer, namely, the amount of radiation absorbed in clouds and the amount of radiation absorbed in the cloud-free atmosphere.

During April 1996, an SSFR prototype was developed for participation in another field experiment, the NASA Subsonic Contrail and Cloud Effect Special Study (SUCCESS), in Lamont, Oklahoma. This prototype is being modified for airborne deployment for the Mission to Planet Earth First International Satellite Cloud Climatology Program (ISCCP) Regional Experiment (FIRE) Phase III Program. An ER-2 test flight is scheduled for winter 1997. Further plans for the SSFR include deployment on a NASA remotely piloted aircraft (RPA). The research initiated during this project will be continued in FIRE III investigations, and will be useful in developing new methods for cloud and aerosol remote sensing.

Publications resulting from study
Reinking, R.; Uttal, T.; Kropfli, R.; Eloranta, E. W.; Piironen, P.; Piironen, A.; Bruintjes, R.; and Pilewskie, P.: Hydrometeor Distinction with Radar, Lidar, Passive Spectro-Radiometer and Aircraft Measurements in a Winter Storm. Paper presented at the International Union of Geodesy and Geophysics, XXI General Assembly, Boulder, Colo., July 2–14, 1995.

Pilewskie, P.; and Twomey, S.: Cloud Properties Derived from Surface-Based Near-Infrared Spectral Transmission. IRS '96: Current Problems in Atmospheric Radiation, A. Deepak Publishing, Fairbanks, Alaska, 1996.

Pilewskie, P.; Goetz, A. F. H.; Bergstrom, R.; and Beal, D.: Surface Measurements of Solar Spectral Radiative Flux in the Cloud-Free Atmosphere. Extended Abstracts, Ninth Conference on Atmospheric Radiation, Long Beach, Calif., 1997.

Pilewskie, Peter: The Effects of Water Vapor and Clouds on the Distribution of Solar Radiation at the Ground. Seminar presented at the Pennsylvania State University, Department of Meteorology, Nov. 14, 1996.

Participation in Arizona Program, Cottonwood, Ariz., Jan.–Feb. 1997.

Participation in NASA Subsonic Contrail and Cloud Effect Special Study (SUCCESS), Lamont, Okla., Apr. 1996.

Keywords
Remote sensing, Clouds and climate

SECTION 2
ONGOING REPORTS

Development of Fiber-Optic Sensors for Studies of Transition from Laminar to Turbulent Flow

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Objectives of the study
To develop a novel transducer technique for real-time measurements of pressure fluctuations in conjunction with studies of the transition from laminar flow to turbulence on an airfoil surface. One of the major tasks in information science is collecting information (sensing or measuring). Measurements in physical sciences are accomplished through interaction of sensors with the system involving the measurand. The interaction should be large enough for a good signal-to-noise ratio, and yet should not be so large as to cause excessive disturbance to the system. Aerodynamic systems involving transitions are often extremely sensitive to a transducer intrusion, which is difficult to avoid with existing sensor techniques. The proposed program exploits fiber-optic (FO) sensor technology, which has been maturing in various industrial applications as well as in research. This technology offers numerous advantages for aerodynamic studies, including high sensitivity, a compact sensor package, a wide dynamic range, a high frequency response, and geometric versatility. The high sensitivity and the compact size can be utilized to minimize flow/sensor interaction noise. The geometric versatility provides great flexibility in configuring the optical fiber as extended sensor elements or sensor arrays. The optical fibers can be implanted on the surface of a solid body, or they can be flush mounted on a surface such as an airfoil with perforation for laminar flow control. Such sensor implanting or mounting is a desirable feature for minimizing flow/sensor interaction noise. Some other advantages of FO sensors include superb telemetry capability, high temperature tolerance, and immunity to electromagnetic interferences. These features are also important in aircraft design as well as in the wind-tunnel test environment.

Progress and results
Fiber Fabry-Perot sensors were designed and plush mounted on a Plexiglas plate for inflow tests. The unit was tested in an anechoic chamber.

Preliminary tests showed that the unit was working but with a sensitivity lower than expected. The sensitivity is good enough for measuring pressure fluctuation equivalent to turbulence generated on the airfoil surface under a flight test condition for which the mean flow Mach number is approximately 0.5. The initial flow test was planned in a draft wind tunnel with a Mach number of 0.1. The magnitude of the turbulence pressure is proportional to the square of the Mach number, and thus the inflow test requires a sensor sensitivity 25 times as high as the flight test condition. The sensor heads are redesigned, and they are currently being fabricated. Anechoic chamber tests and inflow tests will be conducted to demonstrate the proof of concept.

Keywords
Fiber-optic

Size-Density Studies of Chondrules, and Aerodynamic Sorting in the Solar Nebula

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Ames Research Center

Other personnel involved
Monica Rivera, Summer High School
Apprenticeship Program

Objectives of the study
Chondrules are millimeter-diameter, solidified drops of liquid silicate rock. The dominant constituent of the very primitive "chondritic" meteorites, these chondrules show clear evidence for aerodynamic sorting. The properties of chondritic meteorites, or chondrites, are unexplained and have puzzled meteoriticists for over a century. The objective of this study is to examine the relationship between size, density, texture, and rim characteristics of chondrules in several different chondrite types (unequilibrated ordinary, carbonaceous, and enstatite chondrites) and determine what characteristics are a reflection of conditions during formation and residence in the nebula. This information will be used to test and constrain plausible models for the origin and early evolution of primitive meteorite parent bodies in terms of specific nebular processes. Whether the distribution of chondrules in various classes of chondrites can be explained by aerodynamic sorting in the nebula will be examined, as will the extent to which the inclusion of the rim with the chondrule improves or degrades the agreement with an aerodynamic sorting hypothesis.

Progress and results
In order to examine the relationship between size, density, texture, and composition of chondrules from a meteorite, it is necessary to separate, or disaggregate, the sample. Two carbonaceous chondrites have been successfully disaggregated, and a selection of chondrules have been obtained from one ordinary chondrite. Results from the two carbonaceous chondrites indicate that there is a relationship between size and density, although there is significant scatter for the smaller chondrules, probably caused by measurement errors. A significant correlation was found between the volume of the chondrule and the volume of the accretionary rim on a subset of the Allende chondrules. These results are being evaluated in terms of aerodynamic sorting in the nebula. Disaggregation of the two ordinary chondrites will continue, and compositional analysis of the ALH84028 carbonaceous chondrite will be made.

Significance of the results
This project has produced the first measurements of chondrule and rim volumes. The correlation between core and rim volumes on individual chondrules may allow us to place significant constraints on the environment in which rim formation occurred. These results suggest that this suite of chondrules shared the same rimming environment. Accumulation of dust as a rim on a chondrule could be proportional to the exposure time and sweep up rate, or each chondrule could accrete its own mass in material before being stopped.

Keywords
Meteorites, Solar nebula, Aerodynamic sorting

Laser-Spectroscopic Instrument for Turbulence Measurements

Investigator(s)
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Objectives of the study
To develop and demonstrate a laser-spectroscopic instrument that can be used to obtain simultaneous measurements of temperature, density, pressure, and velocity in unseeded, turbulent, compressible air flows.

Progress and results
A new velocity measurement technique using flow-tagging of atomic oxygen is being developed for incorporation into a demonstrated capability for measuring thermodynamic properties using laser-induced fluorescence of O_2. It is envisioned that the interdependence of thermodynamic and velocity fluctuations caused by turbulence could be directly investigated through applications of this previously unavailable instrumental capability. For example, this nonintrusive instrument would allow a direct assessment of the assumption that all the aforementioned fluctuating quantities are uncorrelated, and therefore do not have to be included in numerical models.

Significant progress has been made in establishing the viability of atomic oxygen as a useful flow-tag species. Using existing laser instrumentation, populations of atomic oxygen were created in room air and probed at successively greater time delays to evaluate photochemical mechanisms that would deplete the tag population and limit the applicability of the approach. In addition, through collaboration with other researchers, the feasibility of using ozone as a flow-tag species for extremely long time delays was investigated. A thorough understanding of the 193-nm induced photochemistry has been developed.

During the past fiscal year, both lasers broke down. The dye laser required replumbing and needed a new pump gear for the amplifier circulator. The excimer laser lost the impeller coupler in the oscillator, precipitating a complete rebuild of that chamber. Both lasers are now working. A new, intensified camera system has been ordered, and the investigation can now proceed to the demonstration phase.

The next phase of this investigation will demonstrate the velocity measurement approach in a small-scale, free-jet air-flow facility. In addition, the integration of the velocity measurement approach into the existing thermodynamic property measurement capability will continue.

Keywords
Lasers, Velocimetry, Fluorescence

Computational Modeling of Ultrafast Optical Pulse Propagation in Semiconductor Lasers and Amplifiers

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Objectives of the study

To understand the emerging technology of photonic (or optoelectronic) integrated circuits (PICs or OEICs). In PICs, optical and electronic components are grown together on the same chip. To build such devices and subsystems, one needs to model the entire chip. The importance of PICs is in their use in building integrated optical transmitters, integrated optical receivers, optical data storage systems, optical interconnects, and optical computers.

This research will provide accurate computer modeling of ultrafast optical wave propagation in semiconductors. Such modeling is necessary for the successful development of PICs. More specifically, these computer codes will enable the modeling of such devices, including their subsystems, such as semiconductor lasers and semiconductor amplifiers in which there is femtosecond pulse propagation.

Progress and results

The theory and governing equations have been formulated for modeling the propagation of 50- to 100-femtosecond pulses in semiconductor materials. A finite-difference algorithm has been developed that solves the nonlinear Maxwell's equations and the semiconductor Bloch's equations, without making the standard slowly varying envelope (SVEA) and rotating-wave (RWA) approximations. This more exact formulation is applied to simulations of the propagation of ultrashort pulses for which the standard approximations reach their limits. This development was motivated by the generation of optical pulses as short as 8 fs, which has become possible because of recent progress in ultrafast technology. These combined equations model the optical pulse and the interband and intraband dynamic processes in the semiconductor.

Figure 1 shows gain curves that were obtained under the free-carrier assumption. Figure 2 shows the linear exciton absorption results obtained by including the Coulomb interaction. The 1s and 2s absorption peaks for a 2-ps dipole decay time should be noted.

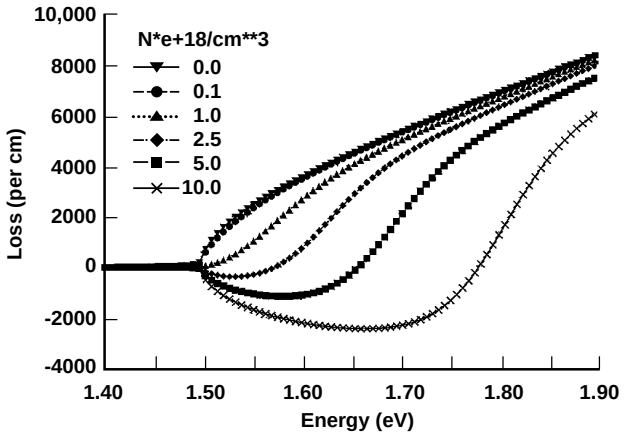

Figure 1. Gain curves.

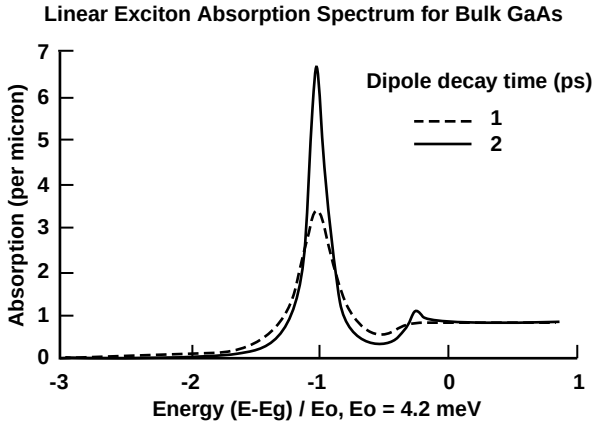

Figure 2. Linear exciton absorption spectrum.

Significance of the results

These calculations of absorption spectrum show that this new, more exact algorithm has the capability of modeling the quantum interactions of ultrafast optical pulses with semiconductor materials.

Publications resulting from study

Goorjian, P. M.; and Agrawal, G. P.: Computational Modeling of Ultrashort Optical Pulse Propagation in Nonlinear Optical Materials. Paper NME31, presented at the Nonlinear Optics Topical Meeting, Maui, Hawaii, July 8–12, 1996.

Keywords

Computational nonlinear optics, Semiconductor and other nonlinear optical materials, Ultrafast (femtosecond) optical pulse propagation

Remote Sensing of Aircraft Contrails Using a Field Portable Imaging Interferometer

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Other personnel involved
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Objectives of the study
To measure visible and infrared radiative effects of aircraft contrails to provide information about their spatial distributions, their microphysical properties (especially ice crystals), their time evolution, and their surroundings by application of a novel remote sensing technique, imaging interferometry. The instrument concept to be utilized is called DASI (digital array scanned interferometry). These measurements will be made from the ground at appropriately selected sites. Analytical techniques employing atmospheric radiative transfer methods will be developed and applied to analysis and interpretation of the spectral images. The overall objective is to demonstrate the feasibility of this measurement technique for remote sensing of contrail properties, and more generally, of aerosol plumes.

Progress and results
In early May 1996 measurements were made during NASA's subsonic aircraft: contrail and cloud effects special study (SUCCESS). Ground-based measurements were made of aircraft contrails and cirrus clouds at the Department of Energy's Cloud and Radiation Testbed (CART) site in Oklahoma. DASI spectral images were acquired for both commercial aircraft and SUCCESS mission aircraft atmospheric radiative effects. These measurements were acquired together with those of other participating sensors. Simultaneously, airborne and satellite-based measurements were also acquired by collaborating investigators.

The contrail measurement result shown in figure 1 was obtained using our near infrared (NIR) DASI instrument. The DASI was pointed toward a fixed coordinate of the sky while the SUCCESS aircraft crossed the field of view. The resulting spectral image contains contrail cross-profile information along the spatial coordinate and contrail evolution information along the time coordinate (0.2-sec intervals). Figure 1 shows time sequential profiles derived from this spectral image.

Plans have been made to make additional ground-based measurements of aircraft contrails within the next few months, when two improved DASI instruments will become available. The improved infrared instrument will permit obtaining images with good spatial resolution over the entire spectral range of 4000 to 11,000 cm^{-1} (0.91 to 2.0 microns). The current IR DASI could not achieve the desired performance over the entire spectral range because of chromatic aberrations and other limitations of the optics. The second DASI will cover the visible to NIR spectral region.

Concurrently, advanced analysis algorithms for the interpretation of the data acquired at the Oklahoma site and at other ground-based locations are being developed.

Significance of the results
The results from the May 1996 measurements have met the following analysis goals: 1) determination of spatial features, extent, and short-term time evolution of the contrails; 2) assessment of spatial distributions—mapping of variations in cirrus optical properties; 3) collection of information about the atmosphere in the vicinity of contrails; 4) qualitative extinction and scattering optical depth information. It should be noted that, over the period between 0 and 2 seconds, the contrail evolves from being a net absorbing to a net scattering feature relative to the region surrounding the contrail. (See fig. 1.) This evolution is a likely indication of the ice nucleation process occurring to form the contrail.

Keywords
Aircraft contrails, Remote sensing, Imaging spectrometers

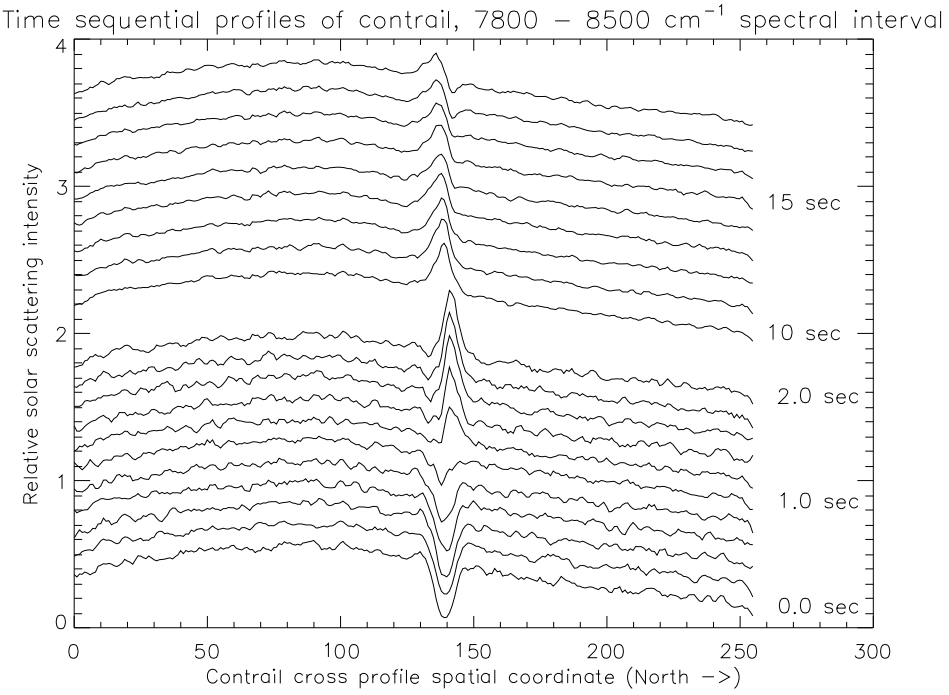

Figure 1. Time sequential profiles of an aircraft contrail derived from a DASI spectral image. A spectral range of 7800 to 8500 cm^{-1} (1.17 to 1.28 microns) was selected for these plots. The horizontal coordinate is in arbitrary units, corresponding to a full field of view of 7.3 deg or 1.28 km at an assumed range of 10 km. The vertical coordinate corresponds to relative solar scattering intensity. Profiles are offset along the vertical coordinate by a quantity proportional to the sampling time to aid in visualization.

Validation of Engine-Change Procedures through Team Task Analysis

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Other personnel involved
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Objectives of the study
To enhance maintenance procedures through the incorporation of team factors elements. Specifically, team coordination principles may be directly operationalized into procedures through explicit directions, notes, suggestions, and standards. The B737 CFM56-7 engine-change operations were used as a testbed for developing the generic procedure analysis system. Research steps include the following:

- Review accident and incident reports related to human factors in maintenance operations
- Develop collaborative plan with Boeing Commercial Airplane Company participants
- Conduct familiarization observations of engine-change activities
- Develop a model procedure evaluation system
- Apply the procedure analysis system to the original and enhanced engine-change procedures
- Validate procedure differences through observations, interviews, videotapes
- Write a guidelines document for incorporating human factors into the procedure evaluation and redesign process

Progress and results
Literature review of accident reports and analysis of incident reports was completed for the purpose of gathering information on team and organizational features that have been linked to incidents and accidents.

Collaborative planning with Boeing participants resulted in the following plan: 1) identification of relevant company participants; 2) obtaining existing documentation on original B737 CFM56-7 engine-change procedures; and 3) obtaining data and documentation on recent B737 engine-change updates (including timeline analyses, videotape records, and existing performance data.

A procedure analysis system was developed and applied to original and updated engine-change procedures, and preliminary summaries of data were generated.

Currently, the procedure analysis system is being validated with experts at Boeing and the system is being refined on the basis of their feedback. In addition, the legal proprietary agreements are being finalized so that the original Boeing videotapes can be obtained and analyzed.

Significance of the results
In order to systematically compare the original and updated engine-change procedures, two levels of coding (structural and functional) have been developed and applied to every procedural item. Structural changes characterize additions, removals, item restructuring (splitting and merging of items), and information changes on the basis of these codes. Functional changes comprise a second-level coding, which characterizes the purposes for making the change (e.g., enhancing situation awareness, time or task management across team members, safety information, referral to resources, clarifications through resequencing, simplified grammar, information refinements, etc.).

Eighty-eight percent of the procedures changed in one way or another, 34 percent were new steps added, and the remaining 54 percent were moved, restructured, or changed with respect to information. One of the functions of adding new steps was to enhance situation awareness. For instance, at the beginning of each main section, a big-picture description of what would follow was placed in a section called “General.” Such enhancements allow teams to better plan ahead and distribute workload and resources efficiently.

The final guidelines will reformulate what is learned from this specific engine-change procedure analysis so that procedure specialists can use the lessons learned to conduct their own procedures assessment and redesign.

Future plans include gaining NASA R&T funding in order to formally extend these findings and the analysis system to airline applications. Airline procedures often require substantial refinement from those provided by the manufacturer (e.g., Boeing) because of differences in goals, policies, and operational practices. Airlines are eager to solve human factors problems, so the opportunity to tailor the procedure analysis system

and guidelines for airline use will guarantee their participation in providing subject matter experts, field experience, and their help in the validation phase.

Publications resulting from study

Veinott, E.; and Kanki, B. G.: Identifying Human Factors Issues in Aircraft Maintenance Operations. Poster presentation at Human Factors and Ergonomics annual meeting and poster session, San Diego, Calif., Oct. 1995.

Kanki, B. G.; and Walter, D.: Reduction of Maintenance Error Potential through Focused Interventions. Paper presented at FAA/AAM Meeting on Human Factors in Aviation Maintenance and Inspection, Mar. 1997, in preparation.

Kanki, B. G.; Dulchinos, V.; and Repp, T.: Guidelines for Integrating Human Factors into Procedure Analysis and Design. NASA TM, in preparation.

Keywords

Maintenance resource management, Human factors in procedure design, Procedure evaluation and redesign

Development of a Silicon-Micromachined Gas Chromatography System for Determination of Planetary Surface Composition

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Objectives of the study
To engineer and fabricate a highly efficient, low-power, lightweight, micromachined gas chromatography (GC) system with a glow discharge detector to be used in gas chromatographic analysis of low-molecular-weight molecules such as oxygen, nitrogen, argon, methane, ethane, carbon monoxide, carbon dioxide, water, and others that may be present in cometary and planetary bodies.

Progress and results
The development of gas chromatographic equipment for planetary atmospheric probes and soil gas or pyrolytic analysis was required for both the Viking mission to Mars and the Pioneer Venus mission. A GC instrument was used for the Pioneer Venus mission. However, future missions such as the Mars exploration missions and missions to probe outer planet atmospheres or moons will require further reduction in weight, volume, and power requirements.

A massive effort is presently under way to revolutionize the technical approach to spacecraft and robotic exploration. The Discovery Program is the first incarnation of this new enterprise. Other programs following it include New Millennium, Micro-spacecraft, and Nanoinstruments. All these enterprises have the common paradigm of better, faster, and cheaper. Clearly, the current technology for future space studies will not likely be viable.

A silicon-micromachined GC system containing detector and column integrated into a small piece of silicon has been studied by several researchers. The problem is that no sensitive detector has been designed and tested. The present study uses the metastable ion detector MID detector principle, replacing the radioactive material with the glow discharge method, which has not been studied on the silicon micromachined GC system. A very narrow discharge distance can be produced and controlled, a helium ionization detector can be produced, and a highly sensitive analysis can be obtained (lower ppm can be detected) though a silicon-micromachined wafer. In addition, a column on the chip with a newly developed, highly efficient silicon polymer material (U.S. patented) will be modified and coated to separate most chemical components. This small and highly sensitive GC system will be able to meet future missions requirements.

In this first year of the project, several micromachined chips with different electrode designs were tested. Several chips have been evaluated and discharge curves of these chips have been made. Further evaluation for GC detector application is in progress.

Keywords
Micromachinery, Chromatograph

Planetary Wind Sensor

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Objectives of the study
A single device to sense wind speed and direction on planet surfaces is needed for current and future planet exploration endeavors. Future Mars explorations plan to use hot-wire anemometers to meet this requirement by placing a series of these devices in a circle to measure the wind direction. Clearly, problems arise with this configuration because the multiple supports will obstruct the very flow it is trying to measure. Moreover, many hot wires around the circle would have to be used in order to measure all possible wind directions with a reasonable degree of accuracy. The velocity range to be sensed is 1–30 m/sec with a frequency response of 1 Hz. Devices other than hot wire anemometers have been used for measuring this range on Earth and may be appropriate for measurements on Mars. A study evaluating devices or techniques commonly used for measuring wind speed and direction was completed in order to select the best device for testing in the Mars wind tunnel at Ames. Because measurements on Mars will be in carbon dioxide at 0.01 atmospheres, some modification of Earth-based devices may be required.

Progress and results
Seven techniques were evaluated in this study:
1. Robinson (cup-type) anemometer, turbine meter, and wind vane
2. Ultrasonic wind sensor
3. Heat transfer techniques—hot wires, hot films, etc.
4. Pressure measurement techniques
5. Laser Doppler techniques
6. Oscillations in wakes behind a cylinder
7. Mechanical deflection techniques

The ultrasonic wind sensor was selected for testing because it offers the best combination of performance and robustness. This sensor consists of three ultrasonic sources/receivers arranged in a horizontal equilateral triangle. By measuring the effective acoustic wave propagation speeds in three different directions, the wind velocity vector and the sound speed can be determined.

Significance of the results
A commercial device, the Handar model 425 ultrasonic wind sensor, was purchased for low-pressure evaluation in the Mars wind tunnel at Ames in FY97. This testing will hopefully identify the modifications required to meet the accuracy requirements at Mars.

Keywords
Wind sensor, Planetary measurements, Mars

Planar Doppler Velocimetry

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Objectives of the study
Recently, several laboratories have shown that planar Doppler velocimetry (PDV) offers an attractive means for measuring three-dimensional (3-D) velocity vectors everywhere in a light sheet placed in a flow. Unlike other optical means of measuring flow velocities, PDV is particularly attractive for use in large wind tunnels where distances to the sample region may be several meters, because it does not require the spatial resolution and tracking of individual scattering particles or the alignment of crossed beams at large distances. To date, demonstrations of PDV (also called Doppler global velocimetry by some authors) have been made either in low-speed flows without quantitative comparison with other measurements or in supersonic flows where the Doppler shift is large and its measurement is relatively insensitive to instrumental errors. Moreover, most reported applications have relied on the use of continuous-wave lasers, which limit the measurement to time-averaged velocity fields. The objective of this study has been to quantitatively define and demonstrate PDV capabilities for applications in large-scale wind tunnels that are intended primarily for the production testing of subsonic aircraft. For such applications, the adequate resolution of low-speed flow fields requires accurate measurements of small Doppler shifts that are obtained at distances of several meters from the sample region. The use of pulsed lasers provides the unique capability to obtain not only time-averaged fields, but also their statistical fluctuation amplitudes and the spatial excursions of unsteady flow regions such as wakes and separations.

Progress and results
To accomplish the objectives, the PDV measurement process was first modeled and its performance evaluated computationally. The noise sources considered included those related to the optical and electronic properties of charged-coupled device (CCD) arrays and to speckle effects associated with coherent illumination from pulsed lasers. The signal noise estimates were incorporated into the PDV signal analysis process and combined with a spectroscopic model of the iodine vapor cell used to discriminate Doppler frequency shifts and with computed scattering signals using a Mie scattering theory for polydisperse smoke particles. The relevant parameters incorporated a range of practical aerodynamic test conditions and facility sizes. The results helped define the optimum values of the instrument parameters, showed that the expected signal levels from a practical PDV system were sufficiently large to allow its useful application in large facilities, and showed that the expected velocity measurement uncertainties were small compared to the mean velocities of interest for most subsonic, large-scale wind tunnel testing.

PDV performance was then demonstrated using several bench-top setups, including a rotating wheel where the exact velocity field was always known everywhere, a turbulent air jet with flow properties that were calibrated using pitot and hot-wire probes, and stationary solid and aerosol targets where only the PDV noise was observed. Images from these targets were used to validate the model description of noise magnitudes and to confirm the minimum velocities that could be resolved. The bench-top experiments also allowed the optical configuration and calibration procedures of the instrument to be developed into a robust and easily operated system that is applicable to the environment of large-scale wind tunnels.

Significance of the results
The PDV measurement capabilities developed in this study demonstrate that PDV offers significant advantages compared to other means of measuring velocity fields in large-scale, subsonic wind tunnels. Measurements obtained from each laser pulse allow the accurate resolution of complete velocity vector fields with speeds as low as 3 m/s. From the pulse-to-pulse data, both mean velocities and their fluctuation amplitudes can be determined in any aerosol-seeded flow with adequate optical access, including complex, 3-D, turbulent flows. The method has no upper limit above which velocity cannot be measured, other than extreme hypersonic flow situations containing strong shock waves in which the necessary scattering particles or aerosols in the flow do not follow the sudden changes in flow speeds or directions. Moreover, the measurement procedures are compatible with the production testing environment of large-scale wind tunnels, the experimental setup is relatively simple, and the system can be operated by trained wind tunnel technicians as a production instrument.

Publications resulting from study

McKenzie, R. L.: Measurement Capabilities of Planar Doppler Velocimetry Using Pulsed Lasers. Applied Optics, vol. 35, no. 6, Feb. 20, 1996, pp. 948–964. (Also AIAA Paper 95-0297, presented at the 33rd Aerospace Sciences Meeting and Exhibit, Reno, Nev., Jan. 9–12, 1995.)

McKenzie, R. L.: Planar Doppler Velocimetry Performance in Low-Speed Flows. AIAA Paper 97-0498, presented at the 35th Aerospace Sciences Meeting and Exhibit, Reno, Nev., Jan. 6–9, 1997.

McKenzie, R. L.: Planar Doppler Velocimetry for Large-Scale Wind Tunnels. To be submitted for presentation at the AGARD 81st Fluid Dynamics Panel Symposium on Advanced Aerodynamic Measurement Technology, Seattle, Wash., Sept. 22–25, 1997.

Keywords

Velocity measurements, Wind tunnel instrumentation, Laser Doppler velocimetry

Quantitative Characterization of Porous Thermal Protection System Microstructures Using Laser Scanning Confocal Microscopy

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Objectives of the study
To investigate the capability of laser scanning confocal microscopy (LSCM) to provide *quantitative* information about the porous microstructure of various thermal protection system (TPS) materials. The idea is to use LSCM to obtain digitally stored representations of the pore structure and to devise computational algorithms to extract numerical values for such quantities as porosity, surface area per volume, pore size and orientation distributions, etc. This information will then be incorporated into various modeling efforts, such as, e.g., internal radiation transport and gas flow in fibrous insulations.

Progress and results
- The first ever experimental LSCM images of fibrous TPS materials have been made on samples of LI-2200, AETB-12, and AETB-20 insulations. These results are promising, and they indicate that the LSCM technique is probably suitable for the envisioned goals of this project.
- Data processing and visualization tools have been identified and brought online.
- Preliminary strategies for extracting desired microstructural parameters from the LSCM data have been identified, including the use of voxel surface and volume counting, stereological relationships, and n-point correlation functions to derive various pore structure parameters in different ways to check for consistency.

The work that is currently under way and will continue throughout the next year includes:
- Optimization of the LSCM process to allow for data gathering from larger sample volumes, by adjusting fluorochrome concentrations;
- Obtaining more experimental data on a wider range of porous TPS materials;
- Writing computer codes for extracting desired quantities from LSCM data and coupling them to existing microstructure analysis and visualization software; and
- Inputting derived information into various computational models of material properties and behavior.

Keywords
Porous material, Laser scanning confocal microscopy, TPS microstructures

A Limited Pressure Cycle Engine for High Specific Output

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Objectives of the study
An engine cycle is proposed to meet the needs of NASA's high-altitude aircraft program by providing a significantly higher power output per pound of engine weight without decreasing the engine life through higher loads or piston speeds. The concept makes use of high-pressure intake charging, three times higher than a nominal turbo or supercharger to increase the air charge density. A direct injection water flash evaporator and direct fuel injection are then used to cool the intake charge and eliminate the work due to compression. A low compression ratio piston chamber then performs the combustion and expansion phases, without any increase in peak pressure but with a reduction in peak temperature. Experimentation will be performed to determine the pressures, temperatures, work ratios, specific fuel consumption, timing adjustments, combustion knock and emissions, and water injection rates that yield optimal power results.

Progress and results
Many engine companies have reviewed the proposed research and provided feedback on key elements of the research program. The Orbital Engine Company has performed an indepth analysis of adapting one of their engines to the requirements of this research program and has expressed interest in conducting the experimental work. The research program has been adapted to the input of industry experts to maximize the amount of research that can be performed for the given funding and a purchase request has been submitted for competition of the work.

Significance of the results
The success of this high-risk research is dependent on locating an industry partner with expertise in spark ignition, internal combustion engines, and direct fuel injection. Since this research is experimental, the typical amount of funding required to investigate such a system is several times the amount available. For this reason, finding an industry partner who is also interested in expanding their knowledge in this specific area will lead to significantly more research results for the same amount of funding.

Keywords
High specific output engine, Water injection, Highly charged turbo

Ultra-Light Entry Systems

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Other personnel involved
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Ames Research Center

Objectives of the study
To develop a very low ballistic coefficient, or "ultra-light," atmospheric entry system applicable to certain classes of planetary exploration missions, including exploring different design and manufacturing strategies. In addition, to develop the sounding rocket as an inexpensive means of further developing and validating numerous advanced and otherwise risky flight concepts.

Progress and results
The overall effort included the development of various theoretical models, as well as work in ground facilities (arc jets), and finally culminating in sounding rocket experiments.

In general, reducing the ballistic coefficient (particularly below 10 kg/m^2) resulted in deceleration at a much higher altitude, where the lower density contributes to a significant reduction in the convective heat transfer rate. This reduction allows for the use of high-temperature ceramic materials (both rigid and flexible) in place of the heavier ablative heat shields commonly in use. Numerous probe design advantages resulted.

The use of the sounding rocket is illustrated in figure 1. A two-stage sounding rocket (Terrier/Black Brant) is lifting a payload section that contains numerous probe experiments. The payload section contains numerous decks, each of which has an "ejection carriage" containing a generic probe experiment. A timed signal initiates a guillotine bolt cutter, which severs a retaining bolt. This event releases the spring-loaded ejection carriage from the sounding rocket. The probe experiment is spring-loaded inside the ejection carriage and is thus separated upon exit (up to 12 experiments can be deployed at 5-second intervals when the vehicle is close to apogee). After deployment at an altitude of 300 miles, the probe experiment stabilizes in a preferred orientation, eventually reaching velocities to Mach 8. In the Mars probe experiment (depicted), the heating rates are relatively low, so the thermal energy absorbed during reentry is quickly reradiated. The heat shield thus need not be discarded, another design advantage. By hinging the parachute on the periphery of the heat shield, the heat shield structure can be used to attenuate the landing shock, allowing for a "mild" landing. At the end of the flight, the individual probes are located via a beacon and the data from the data-acquisition package are downloaded.

Several factors allow for the viability of the experiment. First, the mechanical interfaces were kept extremely simple and "generic" (i.e., able to accommodate a variety of individual entry experiments). Second, the adaption of a small, multichannel data acquisition package allowed for numerous experiments to be carried out at the same time. Thus, the sounding rocket is able to take on features of a "facility" (an aerial ballistic range that spans a wide Mach number range in a single experiment). A first, or piggyback flight, intended to prove the electronic packages, is anticipated in April 1997. The dedicated flight will occur in July 1997 at the White Sands Test Facility in New Mexico.

Significance of the results
The results of the work will aid in the design and development of future atmospheric entry probes and, more generally, decelerator technology. Low ballistic coefficient systems were shown to be attractive, particularly for payloads in the several-kg class. (In terms of a Mars mission, a greater number of small probes could be used per flight opportunity). Both rigid and flexible probe designs were manufactured, with 18.0-inch probes being readied for the sounding rocket flight. In addition, a low ballistic coefficient penetrator concept, applicable to a Mars 1998 flight opportunity, was explored and incorporated into the test plan.

In terms of development methodology, the effort is intended to demonstrate that simple and cost-effective atmospheric experiments can be performed with sounding rockets. This effort, in concert with ground ballistic range and arc-jet tests, forms a complementary flight development system intended to rapidly advance the research/development cycle.

Publications resulting from study

Murbach, Marcus S.; Kourtides, Demetrius; and Chen, Y. K.: Ultra-Light Entry Systems for Planetary Missions. AIAA-96-0616, presented at 34th Aerospace Sciences Meeting and Exhibit, Reno, Nev., Jan. 8–11, 1996.

Murbach, Marcus S.; Kourtides, Demetrius; and Chen, Y. K.: Ultra-Light and Ultra-Precise Mars Missions. Submitted to AIAA 35th Aerospace Sciences Meeting and Exhibit, 1997.

Keywords

Ultra-light, Low ballistic coefficient, Entry probes, Sounding rockets

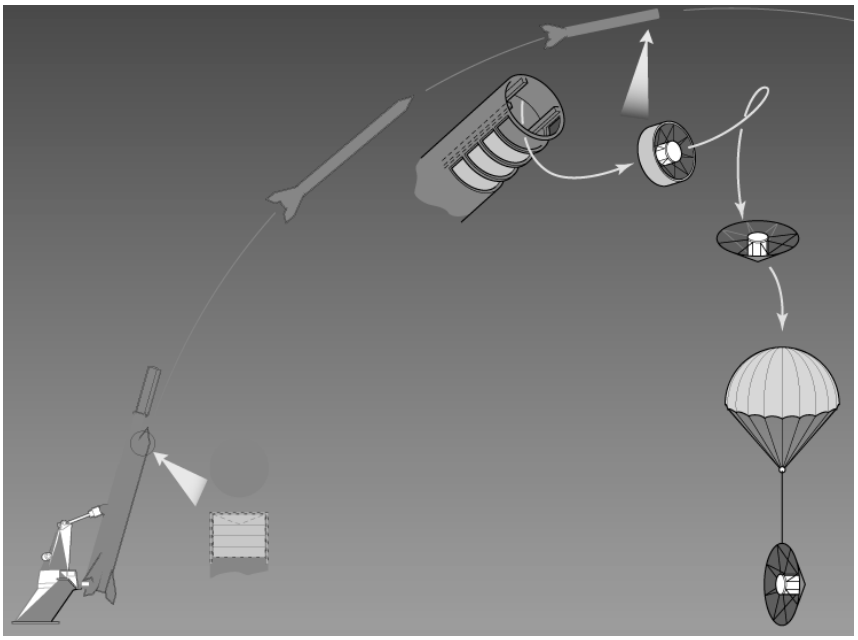

Figure 1. Sounding rocket flight experiment (12 independent experiments per opportunity).

Analysis of Molecular S_2 Spectra Observed during Impact of Comet Shoemaker-Levy 9 with Jupiter

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Objectives of the study
To determine accurate synthetic spectra of the X-B transition in the S_2 molecule in order to analyze spectra taken of the Shoemaker-Levy 9 comet impact with Jupiter.

Progress and results
Significant amounts of diatomic sulfur were detected during recent observations of the impact of Comet Shoemaker-Levy 9 with Jupiter. The X-B (250–320 nm) absorption band of S_2 was observed by the faint object spectrograph (FOS) instrument on the Hubble Space Telescope. An analysis of this spectrum holds promise of providing important information concerning physical conditions (such as the temperature, pressure, density, and sulfur concentration) in the Jovian atmosphere during the comet impact. Such information would provide important data in constraining chemical models of the Jovian atmosphere.

Analysis of this spectral data is dependent on detailed understanding of the X-B transition. Previous experimental studies, limited to the low-lying vibrational levels of the B state ($v' < 9$) because of predissociation of the higher-lying levels, have provided only line positions and Franck-Condon factors. At the request of planetary researchers, electronic structure theory was used to calculate the transition moment for the X-B system and to compute radiative vibrationally and rotationally averaged line intensities. Present calculated theoretical line absorption strengths fit the FOS spectra well for bands that are not predissociated. However, significant enhancement of absorption is observed for $v' \geq 9$ because of predissociation (nonradiative transitions due to crossings by repulsive states dissociating to ground state sulfur atoms). Predissociation will broaden the line profiles, leading to enhanced absorption into vibrational levels $v' \geq 9$ because the absorption is optically thick. Thus, the predissociation gives a measure of the column density.

The predissociation of the higher-lying vibrational levels was studied, requiring determination of the potential energy curves for the X, B, and the perturbing molecular states. In addition, the spin-orbit matrix elements between the ro-vibrational levels of the B and the interacting states were required. Determination of the predissociation line widths using multichannel quantum scattering methods is necessary.

The potential energy curves were determined for all the states dissociating to the two lowest asymptotes. Of these states, only the $^1\Pi_u$, $^3\Pi_u$, $(2)^3\Sigma_u^+$ and $^5\Pi_u$ states are spin-orbit coupled with the B state. High-quality ab initio potential energy curves are being determined for all the states as well as the X and B states. These calculations use an aug-cc-pV5Z basis set employing the CASSCF/ICMRCI+Q method. Calibration calculations are being performed, as the final results are sensitive to the crossing points and the slopes of the potential energy curves at the crossing points. All the calculations were performed using MOLPRO.

Spin-orbit interaction matrix elements were computed with the program SIRIUS/ABACUS/RESPONS at the valence CASSCF level. The basis set employed was the aug-cc-pVTZ basis set of Dunning et al. RESPONS gives matrix elements within a frozen orbitals CI framework using a given reference. It includes the spin-own-orbit and spin-other-orbit two-electron terms from the Breit-Pauli Hamiltonian. The spin-orbit matrix elements between the B state of S_2 and the states that cross it are reported in the interval 3.0–10.0 Bohr. The accuracy of the spin-orbit matrix elements has been assessed by a number of calculations: (1) atomic calculations compared with numerical Dirac-Fock-Breit calculations at the valence CASSCF level and RASSCF level with the 3d orbital in RAS3 with up to 2 electrons, showing that the basis set calculations are small by 10–30 cm^{-1} out of 193; and (2) molecular calculations using different reference states to assess the orbital dependence of the matrix elements. Refinement of the matrix elements by increasing the size of the active space may be necessary for states for which a valence CASSCF calculation does not provide an adequate zeroth order reference. This refinement will be done when the high-quality potential energy curves are completed.

The predissociation line width calculations will be completed when the high-quality potential energy curves are completed.

Publications resulting from study

Pradhan, Atul; and Partridge, Harry: Theoretical Study of the B-X and B″-X Band Systems of S_2. Chem. Phys. Letters, vol. 255, 1996, pp. 163–170.

Keywords

Ab initio, Predissociation, Lifetime

Does Ultraviolet Radiation Affect Carbon Isotope Fractionation?

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Objectives of the study
To determine if ultraviolet (UV) radiation affects stable carbon isotope ratios. If so, is there an ecologic (e.g., microbial mat vs. phytoplankton) or taxonomic (e.g., prokaryote vs. eukaryote, alga vs. plant) correlation with the effect?

Progress and results
These data will provide the basis to present the phenomenon to the scientific community, estimate how widespread the phenomenon is, and to suggest ways to begin to elucidate the mechanisms underly ing the effect. Ultimately this work could lead to a re-interpretation of isotopic ratio studies, including a re-interpretation of the fossil record.

The data so far on the isotopic effect of radiation have been presented at the Inter-American Institute for Global Change Research Workshop on UV in the Marine Environment in Baja, Mexico. Other researchers are being consulted about modifications to the original experimental design.

The next step is to grow organisms outside in the presence and absence of UV and to analyze biomass for $\Delta\delta^{13}C_{org}$ values to determine if there is a difference between treatments.

Keywords
Ultraviolet radiation, Carbon isotope ratios, Global change

Computation of the Low-Temperature Rate Constants for the Reaction $HO_2 + O_3 \rightarrow OH + O_2 + O_2$

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Objectives of the study
The HO/HO_2 catalytic cycle for ozone depletion involves the reactions:

$$HO + O_3 \rightarrow HO_2 + O_2$$
$$HO_2 + O_3 \rightarrow HO + O_2 + O_2$$

The net reaction is $2\ O_3 \rightarrow 3\ O_2$.

The rate constant for the $HO_2 + O_3$ reaction is uncertain in the low-temperature region, and the purpose of these studies is to compute the required rate constant information.

Progress and results
The reaction of HO_2 with O_3 is believed to involve two competing pathways. In the literature it is suggested that one pathway involves H abstraction from HO_2 by O_3 to give $O_2 + HO_3$. From studies of the $H + O_3$ surface it is known that HO_3 is not stable with respect to dissociation to $HO + O_2$. Thus, the ultimate products would be $HO + O_2 + O_2$. The other pathway involves addition of HO_2 to O_3 to give an HO_5 complex. This complex can dissociate to $HO_3 + O_2$ or $HO + O_4$. Once again the $HO_3 + O_2$ channel would lead to $HO + O_2 + O_2$. Calculations on a C_2 symmetry O_4 structure indicate that this species is unstable with respect to $O_2 + O_2$. Thus this pathway also leads to $HO + O_2 + O_2$. Isotopic labeling experiments carried out with ^{18}O labeled HO_2 indicate that, while the abstraction channel is dominant at all temperatures, the addition channel becomes more important at lower temperatures. This result is consistent with the expected inverse temperature dependence for complex formation.

This study characterizes the reaction pathways for the $HO_2 + O_3$ reaction. After these pathways have been characterized, it is planned to combine limited information about the HO_5 system with potential functions for the fragments (HO_2, O_3, HO_3, and O_4) to generate a potential energy surface for the combined system.

Significance of the results
Calculations so far have characterized the pathway for $HO + O_3$ and the pathway for $HO_2 + O_3$, which goes through the HO_5 complex. The HO_3 and O_4 systems have also been characterized in detail, since these are key species in the potential energy surface for these reactions. Recently progress has also been made on the pathway for H abstraction from HO_2 by O_3. This process involves a surface crossing between two doublet surfaces derived from the singlet and triplet states of ozone, respectively.

Publications resulting from study
Walch, Stephen P.: On the HO/HO_2 Catalytic Cycle for Ozone Depletion; I. Computed Potential Energy Surfaces for $HO + O_3$ and $HO_2 + O_3$. J. Chem. Phys., in preparation.

Walch, Stephen P.: On the HO/HO_2 Catalytic Cycle for Ozone Depletion; I. Computed Potential Energy Surfaces for $HO + O_3$ and $HO_2 + O_3$. Paper presented at a symposium on atmospheric chemistry at the ACS meeting, Chicago, Ill., Aug. 1995.

Keywords
Ozone depletion, Potential energy surfaces, Reaction rates

Adaptation of Bone to Mechanical Stimulation: Development and Characterization of a Unique Osteoblast Loading System

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Other personnel involved
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Objectives of the study

1) To develop a cell loading system for investigation of the biochemical and structural response of cells to cyclic mechanical loading. The cell loading system will (a) load each cell uniformly and physiologically; (b) dynamically load cells in cyclic tension, compression, or torsion; and (c) permit real-time microscopic observations of the cells at a single set-point in each loading cycle.
2) To perform scientific characterization tests demonstrating that the loading system will support the intended science. Engineering tests will confirm load uniformity and reproducibility. Biological tests using rat osteoblasts, or bone forming cells, will include measurements of intracellular calcium and glucose-6-phosphate dehydrogenase changes, both characteristic responses to mechanical stimulation. Immunofluorescence localization of integrins, extracellular matrix components, and focal contacts will demonstrate that the required features of cellular attachment and structure can be imaged during loading.
3) To develop a model based on structural analyses to predict changes in the cell shape and number of connections depending on the applied load. Three-dimensional cell shapes will be measured using nonpenetrating fluorescent dyes, and combined with data from Objective 2 to support model development.

Progress and results
Development of the cell loading system was initiated. The requirements for the system were established, and several design approaches were evaluated. An approach was selected, and mockups of several design iterations were developed. Tests of cell chamber biocompatibility were initiated. In parallel, several of the techniques needed to perform the science testing were defined. Integrins, extracellular matrix components, and focal contact components were localized using immunofluorescence techniques. Results indicate that specific components of the putative mechanical signal transduction apparatus were effectively localized.

Significance of the results
The results of the hardware and science technique development to date indicate that the objectives can be accomplished. The eventual science results will determine the role of the osteoblast's cytoskeleton and attachments to the extracellular matrix in responding to mechanical loads. Determination of the mechanisms that osteoblasts use to respond to mechanical loading will lead to a better understanding of the role osteoblasts play in situ in bone as they adapt bone structure in response to daily mechanical loads generated by physical activities, such as walking, or reduced activity as seen in spaceflight.

Keywords
Mechanical load, Osteoblast, Strain, Stress

A New Method to Test Rotor Hover Performance

Investigator(s)
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Objectives of the study
To develop a new concept for obtaining more accurate model rotorcraft hover performance measurements. The problem with current model rotor hover testing is that it is typically performed in a special test cell in order to avoid the wind effects that occur in outdoor testing. Testing in enclosed chambers, however, introduces problems associated with flow recirculation, and, in addition, a degree of unsteadiness that is thought to result from the instability of the rotor wake always occurs. These unsteadiness problems are thought to diminish with rotors that are in a climb state because of the increased rotor/wake distance. The testing of rotors in a simulated climb could, therefore, result in more reliable performance data. However, there are no practical facilities for simulating climb. (Such testing requires a very large test section and low free-stream velocities, and such sections are rare and extremely difficult to schedule.) A proposal, therefore, was made to install a special mounting rig in the settling chamber of the soon-to-be-closed 7- by 10-Foot Subsonic Wind Tunnel and then to demonstrate the efficacy of the testing concept. This settling chamber has a 30-foot cross section, which is sufficiently large for typical model rotors. The maximum free-stream velocity of the test section is about 20 fps, which encompasses typical climb speeds. Equally important is the apparent availability of the facility. The resulting data could produce recirculation-free hover performance data by considering hover as a limiting case as the climb rate approaches zero. In addition, the climb conditions should be readily predicted by special computational fluid dynamics (CFD) methods. The accuracy with which these clean flow cases can be predicted would establish a maximum possible accuracy for the prediction of hover. In summary, the objective of this project is to develop and demonstrate a new, simple, low-cost and more accurate means to perform climb testing.

Progress and results
The ability to perform climb testing in a tunnel settling chamber requires two new capabilities: (1) an apparatus for mounting a rotor rig in the center of a large settling chamber, and (2) a rotor stand capable of operating in a horizontal orientation.

The first requirement was met by designing a sturdy three-legged support that spans the tunnel settling chamber (31 feet across) and places the rotor axis in the center of the section (about 15 feet high). The support was designed to be easily assembled and removed. Hard spots for the attachment of this support system were designed and added to the tunnel structure. In order to facilitate assembly and removal of the total assembly, an overhead crane installation was also designed and fabricated. The entire support assembly has been fabricated and installed in the settling chamber.

The second requirement—a horizontally operatable rotor stand—was designed by using existing components and integrating them with a newly designed structural element. An acceptable rotor balance and a transmission capable of operating in the horizontal mode were available, but neither the transmission nor balance were designed to mate together, nor did they have suitable horizontal mounts. Therefore, a special junction piece that both mates the transmission and balance together and provides a suitable location for horizontal mounting was designed and fabricated. In addition, a new motor mount that permitted the placement of available induction motors at a more convenient port on the transmission was designed. The resulting assembly, transmission, motors, balance, and junction/mount constituted a fairly compact rotor drive system that can be readily mounted on top of the tripod support structure.

The flow about a climbing rotor was found to be far steadier—in fact, this flow appears to be completely steady (quite a surprise). It is clear also that this steadiness is not due to the greater separation of the tip vortices, but rather to the complete absence of recirculation. In this recirculation-free state, the measured rotor performance is a smooth, linear function that is easily extrapolated to zero climb (i.e., hover). It was found that, at low climb rates, recirculation sets in again, resulting in a dramatic departure from the extrapolated performance and providing a first measurement of the effect of recirculation on performance. The magnitude of the measured recirculation effect is such as to cause considerable doubts about standard methods of hover testing.

Flow visualization of the rotor wake was also performed by means of smoke and a strobed light sheet. Because of the unusually steady flow, it was possible to observe wake tip vortex behavior that had not been seen before—and that could be important for rotor wake modeling.

Significance of the results

Climb testing promises to provide a way to obtain rotor axial performance data of unusual quality. Such testing may also be extended to permit superior hover simulations. Data of such quality are necessary because hover performance is a direct determinant of the productivity and economics of helicopters. However, there currently are no facilities for such testing because of their cost. The present setup provides a first such facility, and does so economically by using the settling chamber of the 7- by 10-Foot Subsonic Wind Tunnel. In this project an easy-to-install mount has been developed and shown to work very well. Successful flow results demonstrate the ability to obtain data that are unusually free of contaminating recirculation effects. These data will permit validation of new CFD hover/climb codes and lead to new design methods and more efficient rotors.

Keywords

Hover performance, Vertical climb, Rotor test

Use of Evolving Microbial Systems as a Domain for Development of Autonomous Artificial Intelligence Software

Investigator(s)
David Thompson, Ames Research Center, Moffett Field, CA 94035-1000

R. Levinson and P. Robinson, Caelum-Recom Technologies, Ames Research Center

R. Mancinelli, D. Smernoff, and M. White, SETI Institute, Ames Research Center

Objectives of the study
To achieve advances in artificial intelligence (AI)-based software technology for control, diagnosis, and repair of complex microbial experimental systems, and to gain a better understanding of the role that nitrogen fixing and denitrifying microbial systems play in nutrient cycling, atmospheric evolution, and biogeochemical (BGC) cycles on Earth. The goal is advocation of application of the autonomous control software within NASA (e.g., advanced life support, office space science, autonomous spacecraft).

Progress and results
The growth of *Pseudomonas fluorescens*, a denitrifyer, was monitored and controlled in the bioreactor system under varying oxygen levels from 0 to 100 percent. Traditional control software was designed and implemented (i.e., LabView). AI software elements were then fully integrated with the traditional control via a severable communication link, which operates either on the same platform or via a Web interface. Quantitative and qualitative thermal models were developed and integrated into the AI software architecture.

Publications resulting from study
Smernoff, D. T.; and Mancinelli, R. L.: Terrestrial and Space-Based Applications of Autonomous Instrumentation. Adv. Space Res., 1997 (in press).

Mancinelli, R. L.; Smernoff, D. T.; and White, M. R.: Controlling Denitrification in Closed Artificial Ecosystems. Adv. Space Res., 1997 (in press).

Robinson, P.; Autonomous Design and Execution of Process Controllers for Untended Scientific Instruments. 1st International Conference on Autonomous Agents, Marina del Rey, Calif., Feb. 5–8, 1997.

Keywords
Nutrient cycling, Evolution, Autonomous control

Chaos in Interstellar Chemistry

Investigator(s)
A. G. G. M. Tielens, Ames Research Center, Moffett Field, CA 94035-1000

S. B. Charnley, University of California, Berkeley, CA 94720

B. King, Howard University, Washington, DC 20059

Objectives of the study
To develop a theoretical model for chaos in interstellar chemistry. A fundamental understanding of this phenomenon does not yet exist. The proposed model will aim to determine the factors controlling the onset of chaotic behavior, in particular, to delineate the regions of parameter space in which chaos can occur. One application of the results will be to determine the influence of chaos on the formation of stars and planetary systems through its influence on the degree of ionization and on the abundance of cooling species.

Progress and results
A numerical code that calculates the chemical abundances in interstellar clouds has been developed. The initial version of this code contained approximately 4000 reactions between approximately 500 astronomically relevant species. A much smaller subset (170 reactions between 40 species) was derived that still retains the essential characteristics of the complete chemical network and reproduces the calculations of the full code well. Using this code, a systematic study of the (external) parameter space [cosmic ray ionization, far ultraviolet (FUV) photodissociation and photoionization, temperature, density, elemental abundances] has begun.

Chaos in interstellar chemistry is closely tied to the degree of ionization. The results show the presence of two stable solutions above a density of 2×10^4 cm^{-3}. These solutions are characterized by a high degree of ionization in a largely atomic gas and a low degree of ionization in molecular gas, respectively. The location and extent of this bifurcated region is controlled by the abundance of electron donors in the gas; i.e., atomic species such as S, Na, and Si. These species have low lying ionization potentials and the excess charge tends to collect on them. Results show that a low abundance of atomic electron donors promotes the onset of chaos. A second bifurcation region occurs at a much higher density (1.5×10^7 cm^{-3}). This bifurcation zone is controlled by the oxygen abundance, mainly because O dominates molecular destruction rates through burning reaction.

Significance of the results
Ions are an important stabilizing agent for molecular clouds. Although ions are a trace species in molecular clouds, because of their coupling to the magnetic field they can stabilize molecular clouds against self gravity through magnetic pressure. The star formation rate is then controlled by the slow leaking out of the charged species and the magnetic fields through the process of ambipolar diffusion. Present results indicate that, as the cations diffuse out and the cloud is compressed by gravity to densities in excess of 5×10^4 cm^{-3}, the degree of ionization will suddenly drop, the magnetic field will diffuse out rapidly, and the cloud will collapse to form a star.

Keywords
Chaos, Interstellar chemistry, Star formation

Modeling High Energy Aerocapture Trajectories for Outer Planet Orbiter Missions

Investigator(s)
Paul Wercinski, Ames Research Center,
Moffett Field, CA 94035-1000

Other personnel involved
Periklis Papadopolous and Ethiraj Venkatapathy,
Thermosciences Institute, Palo Alto, CA 94303

Lily Yang, Sterling Software Systems,
Ames Research Center

Objectives of the study
First, to characterize the static aerodynamic coefficients of the axisymmetric biconic shape in realistic flow conditions representative of actual flight trajectory, including the lift and drag coefficients of the entry vehicle at various angles of attack; second, to calculate the heating distribution over the surface of the entry vehicle at various trajectory points; and finally, to determine thermal protection system (TPS) requirements from the coupled heating distributions at several trajectory points. With this analysis, an attempt to incorporate approximate methods of estimating the heating distribution (and subsequent thermal protection material requirements) with an actual trajectory simulation will be assessed and performed if appropriate.

Progress and results
A high-fidelity three-degree-of-freedom aerocapture trajectory simulation code that included all necessary input variables to adequately model atmospheric flight in Neptune's atmosphere was developed. Such variables as vehicle aerodynamics, planet rotation effects, and atmosphere structure were included. Subsequently, a comparison of biconic aerodynamics, which compared Newtonian predicted lift and drag coefficients with full three-dimensional (3-D) Navier–Stokes solutions using the General Aerodynamic Simulation Program (GASP) 3.0, was performed. The solutions used H_2-He finite-rate chemistry, and vibrational equilibrium and modeled an axisymmetric biconic shape at various Reynolds numbers and angles of attack. With improved aerodynamics, trajectory simulations were improved. Heating distributions were estimated for the biconic shape over a wide variety of entry conditions. With the capability to evaluate the impact of entry parameters such as entry velocity, lift/drag ratio, etc., on overall aerothermal heating, it is possible to make design choices that were previously not possible.

Significance of the results
The analysis to date has performed calculations never before undertaken such as modeling aerocapture trajectories and simulated biconic flow fields. The capability to estimate heating distributions has enabled evaluating various aerocapture design issues.

Keywords
Aerocapture, Neptune orbiter, Flow-field calculations

Fastenerless Structural Connections for Tiltrotor Aircraft

Investigator(s)
John Zuk, Ames Research Center,
Moffett Field, CA 94035-1000

Clem Hiel, SVERDRUP, Ames Research Center

Objectives of the study
To conduct innovative research leading to the development of a new class of fastenerless connections, called "snap joints," for assembly of composite structures, with special emphasis on tiltrotor aircraft.

Progress and results
Ideas for snap joints have been formulated. In addition, conceptual designs using computer-aided design (CAD) were developed, and candidate test specimens have been fabricated and developed.

A full-scale generic snap joint illustrating ease of assembly and positive interlocking features has been fabricated.

Significance of the results
The concept will be expanded to three universal snap joint configurations. Plans include a patent application and an industrial partnership.

Keywords
Composites, Snap joints

APPENDIX A-1
FINAL REPORTS

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1996
Final Report

Title of Investigation: Waterproofing the Space Shuttle Tiles

Investigator(s) (show affiliation): Charles W. Bauschlicher, Jr., Ames Research Center, Moffett Field, CA 94035-1000

Funding
Year Initiated: FY95
Expected completion date: FY96

Total prior to FY96: $40,000
Authorized in FY96: $40,000

Total expended in FY96: (Estimated)
In-house: $40,000
Contracts (identify):
Grants (identify):

Requested for FY97, if any:

Status of study: ☒ Completed in FY96 ☐ Continued in FY97

If continued in FY97 ☐ with funds remaining? ☐ with FY97 funds?

If transitioned to other funding, to RTOP (number?):

to Program (name?): to Other (identify):

Purpose of investigation

To investigate possible surface coatings to make silica waterproof at high temperatures, eliminating the need to rewaterproof the Space Shuttle tiles after each flight.

FY96 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

It is expected that one or two journal publications will arise from this work.

Planned future work

None.

Prepared by: Charles Bauschlicher Org. Code: ST M/S: 230-3 Phone: (415) 604-6231

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1996
Final Report

Title of Investigation: Thermal Protection Systems for Reusable Launch Vehicles

Investigator(s) (show affiliation): Jeffrey V. Bowles, Ames Research Center, Moffett Field, CA 94035-1000;
Henry G. Adelman, Thermosciences Institute, Ames Research Center

Funding — Year Initiated: FY95 — Expected completion date: FY96

Total prior to FY96: $40,000 — Authorized in FY96: $40,000

Total expended in FY96: $40,000 (Estimated) — Requested for FY97, if any: _____

In-house

Contracts (identify): $40,000 (Thermosciences Institute)

Grants (identify)

Status of study: ☒ Completed in FY96 ☐ Continued in FY97

If continued in FY97: ☐ with funds remaining? ☐ with FY97 funds?

If transitioned to other funding, to RTOP (number?) _____

to Program (name?) _____ to Other (identify) _____

Purpose of investigation

To upgrade the Ames Research Center's vehicle synthesis code Hypersonic Aircraft Vehicle Optimization Code (HAVOC), which is being used to evaluate reusable launch vehicles (RLVs). Previously, HAVOC assumed that all vehicle surfaces were fully catalytic. However, no material is fully catalytic, and Space Shuttle tile ceramic materials are only slightly catalytic. By modifying HAVOC to simulate partially catalytic surface heating, the thermal protection system (TPS) can be designed with more precision. Other improvements to HAVOC include the addition of a Mangler transformation for nonplanar surfaces and an isentropic expansion from the bow shock to more accurately predict the conditions at the boundary layer edges.

FY96 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

The upgraded HAVOC code is being applied to re-entry vehicles to determine the effects of variable catalytic heating and isentropic expansion of the flow from the nose region. The results are being compared to reacting boundary layer solutions.

Planned future work

Improvements to HAVOC are being continued and the results will be compared to computational fluid dynamics (CFD) predictions of re-entry vehicle flow fields and heating rates.

Prepared by: Jeffrey V. Bowles Org. Code: APS M/S: 237-11 Phone: (415) 604-6651

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1996
Final Report

Title of Investigation: Computer Modeling of the Thermal Conductivity of Cometary Ice

Investigator(s) (show affiliation): Theodore E. Bunch, Michael A. Wilson, and Andrew Pohorille, Ames Research Center, Moffett Field, CA 94035-1000

Funding — Year Initiated: FY95 — Expected completion date: FY96

Total prior to FY96: $40,000 — Authorized in FY96: $40,000

Total expended in FY96: $40,000 (Estimated) — Requested for FY97, if any: _____

- In-house
- Contracts (identify): $40,000 (NCC2-5147
- Grants (identify):

Status of study: ☒ Completed in FY96 ☐ Continued in FY97

If continued in FY97: ☐ with funds remaining? ☐ with FY97 funds?

If transitioned to other funding, to RTOP (number?): _____

to Program (name?): _____ to Other (identify): _____

Purpose of investigation

To use molecular dynamics computer simulations to generate samples of amorphous ice of differing microporosities, to compare the structures of these ice samples with experimentally determined structures, and to calculate the thermal conductivity of the amorphous ices as a function of their microporosity.

FY96 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

Wilson, M. A.; and Pohorille, A.: Modeling the Thermal Conductivity of Astrophysical Ice. Poster presented at the International Society for the Study of the Origins of Life (ISSOL) meeting, Orlean, France, July 21–26, 1996.

Planned future work

We have generated a variety of microporous, amorphous ice structures and computed the thermal conductivity of these structures. There is no anomalous low thermal conductivity, even for low-density (0.7 g/cc) samples. It is likely that the unusually low value of the thermal conductivity obtained experimentally is due to mesoscopic defects, such as cracks, in the ice samples. We will attempt to model these larger scale defects and determine the thermal conductivity of amorphous ice when they are present.

Prepared by: Michael A. Wilson Org. Code: SSX M/S: 239-4 Phone: (415) 604-5496

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1996
Final Report

Title of Investigation: Ultrasensitive Detection of Atmospheric Free Radical Molecules: A Full-Sensitivity Demonstration Prototype

Investigator(s) (show affiliation):
Charles Chackerian, Jr., Ames Research Center, Moffett Field, CA 94035-1000;
Christopher R. Mahon, Space Physics Research Institute, Sunnyvale, CA 94087;
James R. Podolske, Ames Research Center;
Thomas Blake, Battelle/Pacific Northwest Laboratory, Richland, WA 99352

Funding — Year Initiated: FY95 — Expected completion date: FY96

Total prior to FY96: $40,000 — Authorized in FY96: $40,000

Total expended in FY96: (Estimated) — Requested for FY97, if any:

- In-house: $10,000
- Contracts (identify): $30,000 (NCC2-807)
- Grants (identify):

Status of study: ☒ Completed in FY96 ☐ Continued in FY97

If continued in FY97: ☐ with funds remaining? ☐ with FY97 funds?

If transitioned to other funding, to RTOP (number?):

to Program (name?): to Other (identify):

Purpose of investigation

To demonstrate the sensitivity of magnetic rotation spectroscopy at the parts per trillion level for free radical molecular species.

FY96 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

Blake, Thomas A.; Chackerian, Charles, Jr.; and Podolske, James R.: Prognosis for a Mid-Infrared Magnetic Rotation Spectrometer for the in situ Detection of Atmospheric Free Radicals. J. Applied Optics, vol. 35, no. 6, Feb. 20, 1996, pp. 973–985.

Planned future work

Final tests will be performed on NO and NO_2 molecules for parts per trillion sensitivity. Adoption of the instrument for use in DC-8 aircraft will be proposed.

Prepared by: C. Chackerian, Jr. Org. Code: SGP M/S: 245-4 Phone: (415) 604-6300

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1996
Final Report

Title of Investigation: Effects of Ozone Depletion/Ultraviolet Radiation on Plants

Investigator(s) (show affiliation): Hector L. D'Antoni, Ames Research Center, Moffett Field, CA 94035-1000;
Joseph W. Skiles, Johnson Controls World Services, Ames Research Center;
Jerri Mazzurco , Daniel Levy, Heather Brady, and Monica Holder, Ames Research Center

Funding — Year Initiated: FY94 — Expected completion date: FY96

Total prior to FY96: $40,000 — Authorized in FY96: $40,000

Total expended in FY96: (Estimated) — Requested for FY97, if any:
- In-house: $40,000
- Contracts (identify)
- Grants (identify)

Status of study: ☒ Completed in FY96 ☐ Continued in FY97

If continued in FY97: ☐ with funds remaining? ☐ with FY97 funds?

If transitioned to other funding, to RTOP (number?):

to Program (name?): to Other (identify):

Purpose of investigation

To identify indicators of UV-B stress in plants that can be remotely sensed by satellite- and aircraft-borne instruments. It was assumed that current levels of UV-B radiation due to ozone depletion were high enough to perform the proposed experiments. Alfalfa was selected for the experiments because it is an important crop that provides forage for many domestic animals, and because it is representative of plants that exhibit the C3 or "cool season" photosynthetic pathway. The following hypotheses were tested: (1) production of screening pigments in alfalfa plants is stimulated by UV-B radiation; (2) elongation of alfalfa plants is affected by UV-B radiation, (3) phenological stages (i.e., flowering) are controlled by UV-B radiation; and (4) alfalfa plants grown under UV-B exclusion have higher chlorophyll concentration. These hypotheses were validated, but new questions arose, suggesting that more research is needed before a strategy can be devised to use NASA's technology for monitoring, early detection, and policy making applications regarding solar UV-B stress on natural and crop communities.

FY96 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

Four Argentine scientists were trained in this project's methodology, and they agreed to collect information in the Southern Hemisphere in locations close to the limits of the springtime "ozone hole." This project's methodology is also part of our collaboration with scientists of the University of Puerto Rico (Mayaguez Campus) in a five-year study funded by NASA.

Planned future work

This project demonstrated that plants under UV-B stress produce signals that can be extrapolated to plant communities. However, the strongest signal (chlorophyll concentration) needs to be decoded in physiological terms (i.e., ability to capture carbon in the gas exchange process and excitation condition of the chlorophyll molecule under increased UV-B flux). Further work is needed to discriminate between signals produced by UV stress and those produced by seasonal and climatological variables. The future work will allow investigators to use NASA's suite of remote sensing instruments to determine UV stress on a large scale.

Prepared by: H. L. D'Antoni — Org. Code: SGE — M/S: 239-20 — Phone: (415) 604-5149

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1996
Final Report

Title of Investigation: Return to the Red Planet: Remote Sensing Analog Studies as Preparation for Mars Exploration Exobiology

Investigator(s) (show affiliation): Jack D. Farmer and James Brass, Ames Research Center, Moffett Field, CA 94035-1000

Funding — Year Initiated: FY95 — Expected completion date: FY96

Total prior to FY96: ____ — Authorized in FY96: $20,000

Total expended in FY96: (Estimated) — Requested for FY97, if any: ____

In-house

Contracts (identify): $20,000 (Johnson Control World Services)

Grants (identify)

Status of study: ☒ Completed in FY96 ☐ Continued in FY97

If continued in FY97: ☐ with funds remaining? ☐ with FY97 funds?

If transitioned to other funding, to RTOP (number?): ____

to Program (name?): ____ to Other (identify): ____

Purpose of investigation

To define basic spectral and spatial resolution requirements necessary for identifying discrete aqueous mineral deposits from Mars orbit. Aqueous deposits of various types are given high priority as targets for Mars exopaleontology, that is, in exploring for evidence of an ancient Martian biosphere. To effectively target sites on Mars for future landed missions and sample return, identification of such deposits from orbit must be made with confidence. This study utilized high spectral and spatial resolution infrared (IR) spectral data to establish realistic thresholds for spatial and spectral resolution. This information is being used to define nominal instrumentation requirements for future missions for Mars exopaleontology.

FY96 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

The perspective gained from this study helped us to convince the Mars '01 Science Definition Team and the Mars community at large of the need for a mission to obtain high spatial resolution (<100 m/pixel) IR imaging of key exobiology sites during the 2001 mission opportunity to support site selection for the 2003 mission and a sample return in 2005. As a result, the high spatial resolution IR spectrometer has now been included in the announcement of opportunity (AO) for 2001. Results also influenced the path of technology development taken by the digital array scanning interferometer (DASI), an IR mapping version of which will be proposed by an Ames team for the 2001 orbital mission. The data acquired are being analyzed.

Planned future work

Funding through the planetary geology and geophysics program will be pursued to continue the study and expand analog sites to include hydrothermal settings.

Prepared by: Jack D. Farmer Org. Code: SSX M/S: 239-4 Phone: (415) 604-5748

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1996
Final Report

Title of Investigation: Development of Noninvasive, Tissue-Oxygen Sensor for Optimizing Ergonomic Design of Workstations in Space and on Earth

Investigator(s) (show affiliation):
Alan R. Hargens, Ames Research Center, Moffett Field, CA 94035-1000;
Gita Murthy, University of California, Berkeley, Ames Research Center;
Norman J. Kahan, Sports and Occupation Medical Associates, Cupertino, CA 95014;
David M. Rempel, University of California, San Francisco, San Francisco, CA 94143

Funding — Year Initiated: FY95 — Expected completion date: FY96

Total prior to FY96: ____ — Authorized in FY96: $40,000

Total expended in FY96: $40,000 (Estimated) — Requested for FY97, if any: ____

- In-house: $40,000
- Contracts (identify):
- Grants (identify):

Status of study: ☒ Completed in FY96 ☐ Continued in FY97

If continued in FY97: ☐ with funds remaining? ☐ with FY97 funds?

If transitioned to other funding, to RTOP (number?): ____

to Program (name?): ____ to Other (identify): ____

Purpose of investigation

To modify the currently existing near-infrared spectrophotometry (NIRS) probe such that superficial muscles can be studied, and to determine whether NIRS can be used to quantify oxygenation at low levels of muscle loading. Low levels of prolonged static contraction of the upper extremity [less than 20 percent maximum voluntary contraction (MVC)] are common in many occupational settings. NIRS may improve our understanding of the role of oxygenation in work-related repetitive motion disorders so that workstation designs on Earth and in space can be improved.

FY96 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

Murthy, G.; and Hargens, A. R.: Near Infrared Spectroscopy: A Noninvasive Technique for Diagnosing Exertional Compartment Syndrome. Operative Techniques in Sports Medicine, vol. 3, no. 4, 1995, pp. 256–258.

Murthy, G.; Kahan, N. J.; Hargens, A. R.; and Rempel, D. M.: Forearm Muscle Oxygenation Decreases with Low Levels of Voluntary Contraction. Submitted to J. Orthopaedic Research, 1996.

Planned future work

To use NIRS to measure muscle oxygenation as an objective method to evaluate and optimize glovebox design, which will enable astronauts to work for extended periods of time without muscle fatigue.

Prepared by: Alan R. Hargens — Org. Code: SLR — M/S: 239-11 — Phone: (415) 604-5746

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1996
Final Report

Title of Investigation: A Novel Telemetric Biosensor to Monitor Blood pH Online

Investigator(s) (show affiliation): John W. Hines and Chris Somps, Ames Research Center, Moffett Field, CA 94035-1000; Edward Pickering, De Anza Student Intern, Ames Research Center; Marc Madou, Microfabrication Applications, Palo Alto, CA 94306; Sara B. Arnaud, Ames Research Center; David Gibbs and Michael Harrison, University of California, San Francisco, Fetal Treatment Center, San Francisco, CA 94143

Funding — Year Initiated: FY95 — Expected completion date: FY96

Total prior to FY96: — Authorized in FY96: $40,000

Total expended in FY96: (Estimated) — Requested for FY97, if any:

- In-house: $40,000
- Contracts (identify):
- Grants (identify):

Status of study: ☐ Completed in FY96 ☒ Continued in FY97

If continued in FY97: ☐ with funds remaining? ☐ with FY97 funds?

If transitioned to other funding, to RTOP (number?): 199802001

to Program (name?): Advanced Technology Development–Biosensor — to Other (identify):

Purpose of investigation

To design, fabricate, and test a miniaturized pH sensor for chronic, online monitoring of blood and tissue pH levels; to modify an existing, totally implantable biotelemeter to acquire, process, and transmit the pH signals; and to perform in vivo testing of the pH sensor and biotelemeter.

FY96 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

The work described herein has been presented at numerous scientific meetings, including the 13th International Symposium of Biotelemetry in Williamsburg, Va., the 6th International Meeting of Chemical Sensors in Gaithersburg, Md., and the 18th International Conference of the IEEE Engineering in Medicine and Biology Society in Amsterdam, The Netherlands.

Planned future work

During the next fiscal year, this project will be transitioned to the Advanced Technology Development—Biosensors program. Integration and testing of component parts will continue. The system will then be tested in animal models as part of the NASA/UCSF collaboration for improved fetal monitoring.

Prepared by: Chris Somps — Org. Code: JES — M/S: 213-2 — Phone: (415) 604-1914

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1996
Final Report

Title of Investigation: Global Climate Change: The Role of Electron-CO_2 Collisions in the Cooling of the Thermosphere

Investigator(s) (show affiliation): Winifred M. Huo, Ames Research Center, Moffett Field, CA 94035-1000;
C. Dateo, Thermosciences Institute, Ames Research Center

Funding — Year Initiated: FY95 — Expected completion date: FY96

Total prior to FY96: $40,000 — Authorized in FY96: ____

Total expended in FY96: (Estimated) — Requested for FY97, if any: ____

In-house

Contracts (identify): $40,000 (Thermosciences Institute)

Grants (identify)

Status of study: ☒ Completed in FY96 ☐ Continued in FY97

If continued in FY97: ☐ with funds remaining? ☐ with FY97 funds?

If transitioned to other funding, to RTOP (number?) ____

to Program (name?) ____ to Other (identify) ____

Purpose of investigation

Determine accurate electron-impact excitation and deexcitation cross sections for the vibrational bending mode of CO_2 and use these data to evaluate the role of electron-impact excitation in the cooling of the thermosphere. The vibrational excitation and deexcitation rate constants will then be determined from these data for modeling purposes.

FY96 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

The electron-impact excitation cross sections of CO_2 have been determined from threshold to 1 eV electron energy using the Schwinger Multichannel formulation. The results were presented at the 49th Annual Gaseous Electronics Conference, Argonne National Laboratory, Argonne, Ill., Oct. 20–24, 1996.

Planned future work

The threshold result will be validated by carrying out a corresponding calculation using the finite-element Z-matrix method. The cross sections will then be used to derive the excitation rate constants for thermospheric modeling.

Prepared by: Winifred M. Huo Org. Code: STC M/S: 2230-3 Phone: (415) 604-6161

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1996
Final Report

Title of Investigation: Understanding Ion Mobility in Polymer Electrolytes for Lithium-Polymer Batteries

Investigator(s) (show affiliation): Richard L. Jaffe, Ames Research Center, Moffett Field, CA 94035-1000; Grant D. Smith, University of Missouri–Columbia, Columbia, MO 65211; Harry Partridge, Ames Research Center; Brian Annis and David Londono, Oak Ridge National Laboratory, Oak Ridge, TN 37831-6197; Oleg Borodin and Matt Pekny, University of Missouri–Columbia

Funding — Year Initiated: FY94 — Expected completion date: FY96

Total prior to FY96: $40,000 — Authorized in FY96: $40,000

Total expended in FY96: $40,000 (Estimated) — Requested for FY97, if any:

In-house

Contracts (identify)

Grants (identify): $40,000 University of Missouri–Columbia, Columbia, MO (NCC2-903)

Status of study: ☒ Completed in FY96 ☐ Continued in FY97

If continued in FY97: ☐ with funds remaining? ☐ with FY97 funds?

If transitioned to other funding, to RTOP (number?):

to Program (name?): to Other (identify): possible outside funding

Purpose of investigation

To develop a molecular-level understanding of the lithium ion transport process in polymer electrolytes. Ab initio quantum chemistry calculations were used to determine the nature of the lithium salt-polymer interaction and molecular dynamics simulations to probe the electrolyte structure and ion transport mechanism. This information is to be used to create new salt-polymer electrolytes with improved performance for secondary lithium-polymer batteries.

FY96 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

During the first year the emphasis was on deriving a force field to represent the ion-polymer interactions and running tests for very dilute ion concentrations. During FY96 the emphasis was on calibrating and testing this force field for high ion concentrations. A Space Act Agreement is being negotiated with a major battery manufacturer as a follow-up to the DDF project.

Smith, G. D.; Jaffe, R. L.; and Partridge, H.: A Quantum Chemical Study of the Interactions of Li^+, Cl^-, and I^- Ions with Model Ethers. J. Phys. Chem., in press.

Smith, G. D.; Borodin, O.; Pekny, M.; Annis, B.; Londono, D.; and Jaffe, R. L.: Polymer Force Fields from ab initio Studies of Small Model Molecules: Can We Achieve Chemical Accuracy? Submitted to Spectrochemica Acta.

Planned future work

A follow-up project under a Space Act Agreement is possible.

Prepared by: Richard Jaffe Org. Code: STC M/S: 230-3 Phone: (415) 604-6458

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1996
Final Report

Title of Investigation: Nonlinear Interactions between Background Disturbances and Disturbances Generated by Laminar Flow Control (LFC) Devices

Investigator(s) (show affiliation): Lyndell S. King, Ames Research Center, Moffett Field, CA 94035-1000;
Jonathan H. Watmuff, MCAT Institute, Ames Research Center

Funding — Year Initiated: FY95 — Expected completion date: FY96

Total prior to FY96: $40,000 — Authorized in FY96: $40,000

Total expended in FY96: (Estimated) — Requested for FY97, if any: _____

- In-house: $40,000
- Contracts (identify):
- Grants (identify):

Status of study: ☒ Completed in FY96 ☐ Continued in FY97

If continued in FY97: ☐ with funds remaining? ☐ with FY97 funds?

If transitioned to other funding, to RTOP (number?): _____

to Program (name?): _____ to Other (identify): _____

Purpose of investigation

To gain a fundamental understanding of the nonlinear interactions between background disturbances in laminar boundary layers, e.g., longitudinal vortices (Klebanoff modes) and disturbances introduced by laminar flow control (LFC) devices, e.g., Tollmien–Schlichting (TS) waves. To explore the conditions under which the interactions are favorable (e.g., suppression of TS wave growth) or detrimental (e.g., secondary instabilities associated with the vortices).

FY96 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

A technique has been developed for introducing weak streamwise vortices in a controlled manner. The presence of the vortices appears to inhibit the growth of TS waves. However, the vortices are subject to secondary instabilities, which need to be explored.

Watmuff, J. H.: Interactions between Klebanoff Modes and TS Waves. Paper presented at DFD meeting, Amer. Phys. Soc., Syracuse, N.Y., Nov. 24–26, 1996.

Watmuff, J. H.: Interactions between Klebanoff Modes and TS Waves in a Blasius Boundary Layer. AIAA Paper 97-0558, presented at 35th AIAA Aerospace Sciences Meeting and Exhibit, January 6–9, Reno, Nev., 1997a.

Watmuff, J. H.: Detrimental Effects of Almost Immeasurably Small Free-Stream Nonuniformities Generated by Wind Tunnel Screens. AIAA Paper 97-0228, presented at 35th AIAA Aerospace Sciences Meeting and Exhibit, January 6–9, Reno, Nev., 1997b.

Planned future work

A technique has been developed for introducing weak streamwise vortices in a controlled manner by stretching a 0.001-inch-diameter wire, normal to both the flow direction and the leading edge, about 6000 wire diameters upstream. The vortices originate in the vicinity of the stagnation line and appear to be very sensitive to the adverse pressure gradient following the pressure undershoot. Planned future work includes a study on the effects of the pressure gradient on the development of the vortices. Further work is also required to more conclusively determine the stabilizing characteristics on TS waves.

Prepared by: Jonathan H. Watmuff — Org. Code: ADF — M/S: 260-1 — Phone: (415) 604-4150

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1996
Final Report

Title of Investigation: Ground-Based Photometric Detection of Terrestrial-Sized Extrasolar Planets

Investigator(s) (show affiliation): David Koch, Ames Research Center, Moffett Field, CA 94035-1000;
Laurance Doyle, SETI Institute, 2035 Landings Drive, Mountain View, CA 94043

Funding — Year Initiated: FY95 — Expected completion date: FY96

Total prior to FY96: $44,000 — Authorized in FY96: $44,000

Total expended in FY96: (Estimated) — Requested for FY97, if any:

- In-house: $3,000
- Contracts (identify):
- Grants (identify): $41,000 SETI Institute

Status of study: ☒ Completed in FY96 ☐ Continued in FY97

If continued in FY97: ☐ with funds remaining? ☐ with FY97 funds?

If transitioned to other funding, to RTOP (number?):

to Program (name?): to Other (identify):

Purpose of investigation

To perform ground-based photometric observing in collaboration with sites world-wide to detect planets in orbit around the eclipsing binary star CM Draconis. Eclipsing binary orbits are already known to be close to the line-of-sight to the orbiting system, so any planetary transits will have a high probability of detection.

FY96 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

Doyle, L. R., et al.: Detection of Habitable-Sized Planets: A Progress Report. Bull. Am. Astron. Soc., vol. 28, 1996, p. 1110.
Doyle, L. R., et al.: Observations to Detect Planets Around Eclipsing Binary Systems, Bull. Am. Astron. Soc., vol. 27, 1995, p. 1382.

Planned future work

Data analysis will continue. A proposal to detect Earth-sized planets has been submitted in response to the Discovery Announcement of Opportunity, released in FY96.

Prepared by: David Koch Org. Code: SSA M/S: 245-6 Phone: (415) 604-6548

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1996
Final Report

Title of Investigation: Development of an Innovative Neural-Based Telescope Balancing System for the SOFIA/Kuiper Airborne Observatory

Investigator(s) (show affiliation): Robert W. Mah, Ames Research Center, Moffett Field, CA 94035-1000; Michael C. Guerrero, Alessandro L. Galvagni, and Ramin A. Eshaghi, Caelum, Inc., Ames Research Center; Jose L. Winters, NASA Ames Internship and Training Program with the Foothill-DeAnza Community College District

Funding — Year Initiated: FY95 — Expected completion date: FY96

Total prior to FY96: $40,000 — Authorized in FY96: $40,000

Total expended in FY96: $40,000 (Estimated) — Requested for FY97, if any: ____

- In-house: $40,000
- Contracts (identify):
- Grants (identify):

Status of study: ☒ Completed in FY96 ☐ Continued in FY97

If continued in FY97: ☐ with funds remaining? ☐ with FY97 funds?

If transitioned to other funding, to RTOP (number?): ____

to Program (name?): ____ to Other (identify): ____

Purpose of investigation

To develop an innovative, noncontacting method for neural-based telescope balancing. Such a system will improve the efficiency of the balancing task; achieve precise balance; eliminate dependence on expert skills; and improve onboard compensation of mass changes, cabling loading, and aerodynamic loads.

FY96 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

During the previous fiscal year, the instrumentation concept was finalized, the key equipment (including noncontacting infrared sensors, data acquisition boards, portable computer, and graphics software) was procured; the feasibility of using the noncontacting sensor onboard the KAO telescope to accurately measure imbalance motions was determined; a simple hardware testbed was built for initial neural net training and experimentation; a 3-D stereographics dynamics model of the Kuiper Airborne Observatory (KAO) telescope was developed for further experimentation; a 1/2-scale hardware prototype of the KAO telescope was built; and various neural-based balancing methodologies were investigated.

During FY96, the 1/2-scale KAO telescope prototype testbed was completed, neural-based experiments were conducted using this testbed, enhancements to the testbed were implemented, and complementary neural-based approaches for telescope balancing were developed.

Presentation of the results of this DDF to the SOFIA Project Office led to additional funding for further development work. The results from this additional work was presented to the SOFIA Telescope Developers in Germany in January 1997.

Planned future work

The prototype neural-based telescope balancing system will be used to demonstrate the enabling capabilities of neural net technology. Future work may include development of a system for flight onboard SOFIA.

Prepared by: Robert W. Mah — Org. Code: IC — M/S: 269-1 — Phone: (415) 604-6044

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1996
Final Report

Title of Investigation: A Microwave-Pumped Far Infrared Photoconductor

Investigator(s) (show affiliation): Robert E. McMurray, Jr., Ames Research Center, Moffett Field, CA 94035-1000;
Jam Farhoomand, Orion TechnoScience, Palo Alto, CA 94036

Funding — Year Initiated: FY95 — Expected completion date: FY96

Total prior to FY96: $40,000 — Authorized in FY96: $40,000

Total expended in FY96: $40,000 (Estimated) — Requested for FY97, if any: ____

- In-house: $40,000
- Contracts (identify):
- Grants (identify):

Status of study: ☒ Completed in FY96 ☐ Continued in FY97

If continued in FY97: ☐ with funds remaining? ☐ with FY97 funds?

If transitioned to other funding, to RTOP (number?): ____

to Program (name?): ____ to Other (identify): ____

Purpose of investigation

To ascertain the feasibility of microwave-pumping the second step of the ionization process in a cold T = 2 K detector. This feasibility would eliminate the need for the T = 4.2 K high temperatures required for thermal ionization, and would eliminate the associated high dark currents. Such an improvement would allow operation of the detector at full peak responsivity, as at T = 4.2 K, but with much lower thermal leakage current present at T = 2 K.

FY96 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

Farhoomand, J.; McMurray, R. E., Jr.; Haller, E.; Bauser, E.; and Silier, I.: Characterization of High Purity GaAs Far-Infrared Photoconductors. International J. Infrared and Millimeter Waves, vol. 16, no. 6, 1995, pp. 1051–1064.

Planned future work

This project will be continued without additional DDF funding in order to finalize the spectral response and publish the results. The concept can then be applied to existing detectors for space applications, and can be extended to other types of detector materials such as Ge and Si.

Prepared by: Robert E. McMurray Org. Code: SFT M/S: 244-10 Phone: (415) 604-3179

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1996
Final Report

Title of Investigation: A Search Technique for Discovering Earth-Crossing Comets from Meteor Stream Outbursts and Determining their Orbits in Space

Investigator(s) (show affiliation): David Morrison and Peter Jenniskens, Ames Research Center, Moffett Field, CA 94035-1000

Funding — Year Initiated: FY95 — Expected completion date: FY96

Total prior to FY96: $40,000 — Authorized in FY96: $40,000

Total expended in FY96: (Estimated) — Requested for FY97, if any:

- In-house: $40,000
- Contracts (identify):
- Grants (identify):

Status of study: ☒ Completed in FY96 ☐ Continued in FY97

If continued in FY97: ☐ with funds remaining? ☐ with FY97 funds?

If transitioned to other funding, to RTOP (number?):

to Program (name?): to Other (identify):

Purpose of investigation

To develop techniques and explore the possibility of measuring orbital elements of meteoroids in meteor outbursts in order to search for Earth-threatening comets through their meteor signatures and determine their orbits in space.

FY96 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

In FY96, we discovered a tool of predicting far-comet type outbursts and predicted such an outburst to occur on November 22, 1995. This event did happen and we succeeded in measuring the orbits of ten outburst meteoroids.

1. Jenniskens, P.: Good Prospects for a-Monocerotid Outburst in 1995. WGN, J. IMO, vol. 23, 1995, pp. 84–86.
2. Jenniskens, P.: High Leonid Activity on November 17–18 and 18–19, 1994. WGN, J. IMO, vol. 22, 1994, pp. 194–198.
3. Jenniskens, P.: Meteor Stream Activity. I. The Annual Streams. Astron. and Astrophys., vol. 287, 1994, pp. 990–1013.

Planned future work

A proposal has been submitted to the Planetary Astronomy Program to solicit funds for future research.

Prepared by: P. Jenniskens — Org. Code: SSX — M/S: 239-4 — Phone: (415) 604-3086

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1996
Final Report

Title of Investigation: Using Ecosystem Science and Technology to Balance the Conservation of Water Supply and Native Hawaiian Forests

Investigator(s) (show affiliation): Robyn Lee Myers, Ames Research Center, Moffett Field, CA 94035-1000

Funding — Year Initiated: FY95 — Expected completion date: FY96

Total prior to FY96: $6000 — Authorized in FY96: $6000

Total expended in FY96: (Estimated) — Requested for FY97, if any:
- In-house: $6000
- Contracts (identify)
- Grants (identify)

Status of study: ☒ Completed in FY96 ☐ Continued in FY97

If continued in FY97: ☐ with funds remaining? ☐ with FY97 funds?

If transitioned to other funding, to RTOP (number?):

to Program (name?): to Other (identify): U.C. Davis dissertation

Purpose of investigation

To use current, multiscale technology to evaluate vegetation changes in the watershed ecosystem, specifically to detect patterns of alien species invasion into native Hawaiian rainforests, and the concurrent loss of biodiversity.

FY96 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

Numerous publications have resulted from this research; they are available on the World Wide Web at http://ice.ucdavis.edu/~robyn/curvitae.html.

Planned future work

Prepared by: Robyn Myers — Org. Code: SGE — M/S: 242-4 — Phone: (415) 604-5899

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1996
Final Report

Title of Investigation: A New Method for Measuring Cloud Liquid Water Using Near Infrared Remote Sensing

Investigator(s) (show affiliation): Peter Pilewskie, Ames Research Center, Moffett Field, CA 94035-1000

Funding — Year Initiated: FY95 — Expected completion date: FY96

Total prior to FY96: $40,000 — Authorized in FY96:

Total expended in FY96: $40,000 (Estimated) — Requested for FY97, if any:
- In-house: $15,000
- Contracts (identify): $25,000 (Prof. S. Twomey)
- Grants (identify):

Status of study: ☒ Completed in FY96 ☐ Continued in FY97

If continued in FY97: ☐ with funds remaining? ☐ with FY97 funds?

If transitioned to other funding, to RTOP (number?): 622-43-01-10

to Program (name?): First ISCCP Regional Experiment, Phase III (FIRE III) — to Other (identify):

Purpose of investigation

To develop cloud remote sensing methods for inferring the liquid water content (LWC) of clouds, which includes the subsequent development of experimental [a solar spectral flux radiometer (SSFR)] and theoretical tools necessary for cloud property retrievals. Because the LWC in clouds is so crucial in the regulation of the Earth's hydrological cycle and therefore has direct climate implications, and because cloud water content has been so poorly sampled because of its dependence on temperature, this effort to use a near infrared (NIR) remote sensing technique was initiated. Measurements of NIR scattered by clouds have been used in past studies to infer cloud properties such as particle size, cloud thickness, and thermodynamic phase of cloud water, with varying degrees of success. The objectives of this study are to use a similar approach in determining cloud water content by measuring the NIR solar spectrum transmitted through clouds and deriving the relationship between the spectral information and cloud water content.

FY96 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

Reinking, R.; Uttal, T.; Kropfli, R.; Eloranta, E. W.; Piironen, P.; Piironen, A.; Bruintjes, R.; and Pilewskie, P.: Hydrometeor Distinction with Radar, Lidar, Passive Spectro-Radiometer and Aircraft Measurements in a Winter Storm. Paper presented at the International Union of Geodesy and Geophysics, XXI General Assembly, Boulder, Colo., July 2–14, 1995.

Pilewskie, P.; and Twomey, S.: Cloud Properties Derived from Surface-Based Near-Infrared Spectral Transmission. IRS '96: Current Problems in Atmospheric Radiation, A. Deepak Publishing, Fairbanks, Alaska, 1996.

Pilewskie, P.; Goetz, A. F. H.; Bergstrom, R.; and Beal, D.: Surface Measurements of Solar Spectral Radiative Flux in the Cloud-Free Atmosphere. Extended Abstracts, Ninth Conference on Atmospheric Radiation, Long Beach, Calif., 1997.

Pilewskie, Peter: The Effects of Water Vapor and Clouds on the Distribution of Solar Radiation at the Ground. Seminar presented at the Pennsylvania State University, Department of Meteorology, Nov. 14, 1996.

Participation in Arizona Program, Cottonwood, Ariz., Jan.–Feb. 1997.

Participation in NASA Subsonic Contrail and Cloud Effect Special Study (SUCCESS), Lamont, Okla., Apr. 1996.

Planned future work

The research will be continued in the Mission to Planet Earth First International Satellite Cloud Climatology Program (ISCCP) Regional Experiment (FIRE) Phase III Program. Plans are currently under way to develop an airborne version of the SSFR that was built during this project. An ER-2 test flight is anticipated in winter 1997, with FIRE flight missions expected in FY98. Further plans are under way to fly an SSFR on a NASA remotely piloted aircraft (RPA). Arizona Program and SUCCESS field experiment data are currently being analyzed. In addition, consideration is being given to apply both the instrumentation and analysis methods to the problem of aircraft icing.

Prepared by: P. Pilewskie — Org. Code: SGP — M/S: 245-4 — Phone: (415) 604-0746

APPENDIX A-2
ONGOING REPORTS

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1996

Title of Investigation: Development of Fiber-Optic Sensors for Studies of Transition from Laminar to Turbulent Flow

Investigator(s) (show affiliation): Y. C. Cho, N. N. Mansour, and R. D. Mehta, Ames Research Center, Moffett Field, CA 94035-1000

Funding — Year Initiated: FY95 — Expected completion date: FY97

Total prior to FY96: $40,000 — Authorized in FY96: $40,000

Total expended in FY96: $40,000 (Estimated) — Requested for FY97, if any: _____

- In-house: $22,000
- Contracts (identify): $8000 (Mike Layton)
- Grants (identify): $10,000 (Rutgers University)

Status of study: ☐ Completed in FY96 ☒ Continued in FY97

If continued in FY97: ☒ with funds remaining? ☐ with FY97 funds?

If transitioned to other funding, to RTOP (number?) _____

to Program (name?) _____ to Other (identify) _____

Purpose of investigation

To develop a novel transducer technique for real-time measurements of pressure fluctuations in conjunction with studies of the transition from laminar flow to turbulence on an airfoil surface. The proposed program will exploit fiber-optic sensor technology, which has been maturing in various industrial applications as well as in research.

FY96 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

None. This investigation just started recently.

Planned future work

Fiber Fabry-Perot sensors have been designed and fabricated, and preliminary tests of the sensor performance have been conducted. The sensitivity is adequate for a flight test condition (M = 0.5). However, we decided that the design needs to be modified for increased sensitivity to measure turbulence generated in a lab wind-tunnel test condition (M = 0.1). The proof of concept tests will be conducted with the newly designed sensors in a draft wind tunnel.

Prepared by: Y. C. Cho — Org. Code: IC — M/S: 269-3 — Phone: (415) 604-4139

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1996

Title of Investigation: Size-Density Studies of Chondrules, and Aerodynamic Sorting in the Solar Nebula

Investigator(s) (show affiliation): Jeff Cuzzi, Ames Research Center, Moffett Field, CA 94035-1000;
Julie Paque, SETI Institute, Ames Research Center;
Monica Rivera, Summer High School Apprenticeship Program

Funding — Year Initiated: FY95 — Expected completion date: FY97

Total prior to FY96: $28,000 — Authorized in FY96: $32,000

Total expended in FY96: (Estimated) — Requested for FY97, if any:

In-house

Contracts (identify)

Grants (identify): $32,000 (to be added to NASA cooperative agreement NCC 2-887)

Status of study: ☐ Completed in FY96 ☒ Continued in FY97

If continued in FY97: ☒ with funds remaining? ☐ with FY97 funds?

If transitioned to other funding, to RTOP (number?):

to Program (name?): to Other (identify):

Purpose of investigation

To determine if there is a relationship between the size, density, texture, and composition of chrondrules in a variety of chondrites. The results from these experiments will be used to refine models that constrain conditions in the solar nebula.

FY96 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

The experimental method for disaggregation of chondrules was refined during FY96. An abstract including the results of the experiments will be submitted to the Lunar and Planetary Science Conference for presentation in March 1997.

Planned future work

Two additional Antarctic chondrites were obtained in September 1996. Both are ordinary chondrites and will be used for comparison with the two carbonaceous chondrite data sets previously obtained. One of the samples consists of more than 100 chondrules picked from the fines in the sample collection at the NASA Johnson Space Center. This data set is ready for size, density, and compositional measurement.

Prepared by: Jeff Cuzzi/Julie Paque Org. Code: SST M/S: 245-3 Phone: (415) 604-6343/0489

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1996

Title of Investigation: Laser-Spectroscopic Instrument for Turbulence Measurements

Investigator(s) (show affiliation): Douglas G. Fletcher, Ames Research Center, Moffett Field, CA 94035-1000

Funding — Year Initiated: FY95 — Expected completion date: FY98

Total prior to FY96: $40,000 — Authorized in FY96: $40,000

Total expended in FY96: $40,000 (Estimated) — Requested for FY97, if any: ____

- In-house: $40,000
- Contracts (identify):
- Grants (identify):

Status of study: ☐ Completed in FY96 ☒ Continued in FY97

If continued in FY97: ☒ with funds remaining? ☐ with FY97 funds?

If transitioned to other funding, to RTOP (number?): ____

to Program (name?): ____ to Other (identify): ____

Purpose of investigation

To develop a laser-spectroscopic instrument that can be used to obtain simultaneous measurements of density, temperature, pressure, and velocity in unseeded, turbulent, compressible air flows.

FY96 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

None.

Planned future work

The current camera will be upgraded to an intensified charged coupled device (CCD) system to complete the velocity measurement capability development. Subsequently, the velocity and thermodynamic property measurement capability would be demonstrated in the shear layer flow of a small-scale, free-jet air flow.

Prepared by: Douglas G. Fletcher — Org. Code: STA — M/S: 230-2 — Phone: (415) 604-1647

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1996

Title of Investigation: Computational Modeling of Ultrafast Optical Pulse Propagation in Semiconductor Lasers and Amplifiers

Investigator(s) (show affiliation): Peter M. Goorjian, Ames Research Center, Moffett Field, CA 94035-1000;
Govind P. Agrawal, The Institute of Optics, University of Rochester, Rochester, NY 14627;
Rolf Binder, Optical Sciences Center, University of Arizona, Tucson, AZ 85721

Funding — Year Initiated: FY95 — Expected completion date: FY97

Total prior to FY96: $40,000 — Authorized in FY96: $40,000

Total expended in FY96: $40,000 (Estimated) — Requested for FY97, if any: ____

- In-house: $3397
- Contracts (identify):
- Grants (identify): $36,603 (NCC2-5149)

Status of study: ☐ Completed in FY96 ☒ Continued in FY97

If continued in FY97: ☒ with funds remaining? ☐ with FY97 funds?

If transitioned to other funding, to RTOP (number?): ____

to Program (name?): ____ to Other (identify): ____

Purpose of investigation

Develop computer codes to model optical pulse propagation in semiconductor material on the level of quantum optoelectronics. The algorithm solves the combined nonlinear Maxwell's equations of electromagnetics and the semiconductor Bloch equations for the propagation of short optical pulses on the order of 50–100 femtoseconds.

FY96 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

Goorjian, Peter M.: Photonic Switching Devices Using Light Bullets. Patent granted Sept. 12, 1996.
Goorjian, Peter M.: Meeting paper presented at Semiconductor Device Modeling Workshop, Ames Research Center, Mar. 28, 1996.
Goorjian, Peter M.; and Agrawal, Andrew Hulse: Computational Modeling of Ultrashort Optical Pulse Propagation in Nonlinear Optical Materials. Paper NME31, presented at the Nonlinear Optics Topical Meeting, Maui, Hawaii, July 8–12, 1996.
Goorjian, Peter M.: Invited lecture presented at University of Minnesota Supercomputer Institute and Institute of Math, Apr. 17–18, 1996.

Planned future work

To complete modeling of semiconductor material to include many-body effects due to Coulomb interaction and to include more accurate modeling of intraband scattering processes for ultrashort optical pulse propagation. Also, to apply the code to the simulation of novel ultrafast optoelectronic devices.

Prepared by: Peter M. Goorjian — Org. Code: ADC — M/S: T27B-1 — Phone: (415) 604-5547

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1996

Title of Investigation: Remote Sensing of Aircraft Contrails Using a Field Portable Imaging Interferometer

Investigator(s) (show affiliation): Philip D. Hammer, Ames Research Center, Moffett Field, CA 94035-1000;
William H. Smith, Washington University, St. Louis MO 63130;
Stephen Dunagan and Anthony Strawa, Ames Research Center

Funding — Year Initiated: FY95 — Expected completion date: FY97

Total prior to FY96: $40,000 — Authorized in FY96: $40,000

Total expended in FY96: (Estimated) — Requested for FY97, if any:

- In-house: $35,000
- Contracts (identify):
- Grants (identify): $5000 (Washington University Consortium)

Status of study: ☐ Completed in FY96 ☒ Continued in FY97

If continued in FY97: ☒ with funds remaining? ☐ with FY97 funds?

If transitioned to other funding, to RTOP (number?):

to Program (name?): to Other (identify):

Purpose of investigation

To measure visible and infrared radiative effects of aircraft contrails to provide information about their spatial distributions, their microphysical properties (especially ice crystals), their time evolution, and their surroundings. This objective is being accomplished by applying a novel remote sensing technique, imaging interferometry, which provides two-dimensional spectral images of contrails and other atmospheric features of interest.

FY96 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

During early May, measurements were made during NASA's subsonic aircraft: contrail and cloud effects special study (SUCCESS). Ground-based measurements were made of aircraft contrails and cirrus clouds at the Department of Energy's Cloud and Radiation Testbed (CART) site in Oklahoma. DASI spectral images of contrails were acquired during SUCCESS mission aircraft overflights. Results from these measurements were presented at the Director's Discretionary Fund Poster session on October 22, 1996.

Planned future work

Plans have been developed to make additional ground-based measurements of aircraft contrails within the next few months when two improved DASI instruments will become available. The improved infrared instrument will permit obtaining images with good spatial resolution over the entire spectral range of 4000 to 11,000 cm^{-1} (0.91 to 2.0 microns). The second DASI will cover the visible to near infrared spectral region. Concurrently, advanced analysis algorithms for the interpretation of the data acquired at the Oklahoma site as well as at other ground-based locations are being developed.

Prepared by: Philip Hammer — Org. Code: SGE — M/S: 242-4 — Phone: (415) 604-3383

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1996

Title of Investigation: Validation of Engine-Change Procedures through Team Task Analysis

Investigator(s) (show affiliation): Barbara G. Kanki , Ames Research Center, Moffett Field, CA 94035-1000;
Vicki Dulchinos, San Jose State University Foundation, Ames Research Center

Funding — Year Initiated: FY95 — Expected completion date: FY97

Total prior to FY96: $40,000 — Authorized in FY96: $40,000

Total expended in FY96: $40,000 (Estimated) — Requested for FY97, if any: None
- In-house: $40,000
- Contracts (identify):
- Grants (identify):

Status of study: ☐ Completed in FY96 ☒ Continued in FY97

If continued in FY97: ☒ with funds remaining? ☐ with FY97 funds?

If transitioned to other funding, to RTOP (number?): unknown at this time

to Program (name?): NASA R&T — to Other (identify):

Purpose of investigation

To enhance aircraft maintenance procedures through the incorporation of team factors. Using the B737 CFM56-7 engine-change operations as a testbed, the research goal is to develop a generic procedure analysis system for assessing and redesigning maintenance procedures.

FY96 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

Veinott, E.; and Kanki, B. G.: Identifying Human Factors Issues in Aircraft Maintenance Operations. Poster presentation at Human Factors and Ergonomics annual meeting and poster session, San Diego, Calif., Oct. 1995.

Kanki, B. G.; and Walter, D.: Reduction of Maintenance Error Potential through Focused Interventions. Paper presented at FAA/AAM Meeting on Human Factors in Aviation Maintenance and Inspection, Mar. 1997, in preparation.

Kanki, B. G.; Dulchinos, V.; and Repp, T.: Guidelines for Integrating Human Factors into Procedure Analysis and Design. NASA TM, in preparation.

Planned future work

To complete the DDF:
- Validate procedure differences through observations, interviews, and videotapes
- Write a guidelines document for incorporating human factors into the procedure evaluation and redesign process

Beyond the scope of the DDF:
- Extend guidelines for airline application
- Tailor guidelines for airline goals, policies, and procedures
- Validate through observations and interviews with airline subject matter experts

Prepared by: B. G. Kanki — Org. Code: AFO — M/S: 262-4 — Phone: (415) 604-5785

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1996

Title of Investigation: Development of a Silicon-Micromachined Gas Chromatography System for Determination of Planetary Surface Composition

Investigator(s) (show affiliation): Daniel Kojiro, Ames Research Center, Moffett Field, CA 94035-1000;
Thomas Shen, SETI Institute, Ames Research Center; James Suminto and
Frank Yang, Micro-Tech Scientific, Inc., 140 S. Wolfe Rd., Sunnyvale, CA 94086

Funding Year Initiated: FY96 — Expected completion date: FY97

Total prior to FY96: $40,000 — Authorized in FY96: $40,000

Requested for FY97, if any: $40,000

Total expended in FY96:	(Estimated)	
In-house	$2250	$2000
Contracts (identify)	$13,450 Micro-Tech Scientific, Inc.	$20,000
Grants (identify)	$24,300 NCC 2-650	$18,000

Status of study: ☐ Completed in FY96 ☒ Continued in FY97

If continued in FY97: ☐ with funds remaining? ☒ with FY97 funds?

If transitioned to other funding, to RTOP (number?) _____

to Program (name?) _____ to Other (identify) _____

Purpose of investigation

To engineer and fabricate a highly efficient, low-power, lightweight, micromachined GC system with a glow discharge detector to be used in gas chromatographic analysis of low-molecular-weight molecules such as oxygen, nitrogen, argon, methane, ethane, carbon monoxide, carbon dioxide, water, and others that may be present in cometary and planetary bodies.

FY96 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

In the first year of the project, several micromachined chips with different electrode designs were prepared and tested. The preliminary devices produced discharge at 300 volts. The discharge also creates photons that can be identified by a charged coupled device (CCD) detector. This idea has been submitted for Planetary Instrument Definition Development Program (PIDDP) funding.

Planned future work

The chip will be redesigned to obtain more stable discharge current using metal oxide to replace gold as a discharge electrode for longer discharge life.

Prepared by: Thomas Shen/ Daniel Kojiro — Org. Code: SSX — M/S: 239-12 — Phone: (415) 604-5769

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1996

Title of Investigation: Planetary Wind Sensor

Investigator(s) (show affiliation): Paul Kolodziej, Ames Research Center, Moffett Field, CA 94035-1000;
David W. Bogdanoff, Eloret Institute, Ames Research Center;
Gregory Wilson, Arizona State University, Ames Research Center

Funding — Year Initiated: FY96 — Expected completion date: FY97

Total prior to FY96: ____ — Authorized in FY96: $40,000

Total expended in FY96: (Estimated) — Requested for FY97, if any: $40,000

- In-house: $25,000
- Contracts (identify): $15,000 (Eloret Institute)
- Grants (identify):

Status of study: ☐ Completed in FY96 ☒ Continued in FY97

If continued in FY97: ☐ with funds remaining? ☒ with FY97 funds?

If transitioned to other funding, to RTOP (number?): ____

to Program (name?): ____ to Other (identify): ____

Purpose of investigation

A single device to sense wind speed and direction on planet surfaces is needed for current and future planet exploration endeavors. After surveying seven techniques for robustness and performance, an ultrasonic wind sensor that measures the effective acoustic wave propagation speeds in three different directions to determine the wind velocity vector and the sound speed was selected for evaluation in the Mars wind tunnel at Ames.

FY96 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

Planned future work

A commercial device, the Handar model 425 ultrasonic wind sensor, was purchased for low-pressure evaluation in the Mars wind tunnel at Ames in FY97. This testing will hopefully identify the modifications required to meet the accuracy requirements at Mars. Handar has expressed an interest in modifying model 425 after this testing is complete.

Prepared by: Paul Kolodziej — Org. Code: STM — M/S: 234-1 — Phone: (415) 604-0356

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1996

Title of Investigation: Planar Doppler Velocimetry

Investigator(s) (show affiliation): Robert L. McKenzie, Ames Research Center, Moffett Field, CA 94035-1000

Funding — Year Initiated: FY94 — Expected completion date: FY97

Total prior to FY96: $40,000 — Authorized in FY96: $40,000

Total expended in FY96: (Estimated) — Requested for FY97, if any:

- In-house: $40,000
- Contracts (identify):
- Grants (identify):

Status of study: ☐ Completed in FY96 ☒ Continued in FY97

If continued in FY97: ☒ with funds remaining? ☐ with FY97 funds?

If transitioned to other funding, to RTOP (number?):

to Program (name?): to Other (identify):

Purpose of investigation

Development of a planar Doppler velocimetry instrument system using a pulsed laser to provide instantaneous measurements of three-dimensional velocity fields in production-size wind tunnels.

FY96 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

McKenzie, R. L.: Measurement Capabilities of Planar Doppler Velocimetry Using Pulsed Lasers. Applied Optics, vol. 35, no. 6, Feb. 20, 1996, pp. 948–964. (Also AIAA Paper 95-0297, presented at the 33rd Aerospace Sciences Meeting and Exhibit, Reno, Nev., Jan. 9–12, 1995.)

McKenzie, R. L.: Planar Doppler Velocimetry Performance in Low-Speed Flows. AIAA Paper 97-0498, presented at the 35th Aerospace Sciences Meeting and Exhibit, Reno, Nev., Jan. 6–9, 1997.

Planned future work

Development will continue to demonstrate single-pulse velocity measurements in a complex, 3-D flow in the Ames 30- by 40-Inch Wind Tunnel in the Fluid Mechanics Laboratory and, eventually, in the Ames 12-Foot Pressure Wind Tunnel.

Prepared by: Robert McKenzie Org. Code: ADF M/S: 260-1 Phone: (415) 604-6158

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1996

Title of Investigation: Quantitative Characterization of Porous Thermal Protection System Microstructures Using Laser Scanning Confocal Microscopy

Investigator(s) (show affiliation): Frank Milos, Ames Research Center, Moffett Field, CA 94035-1000;
Jochen Marschall, Eloret Institute, Sunnyvale, CA 94087;
Joanne Frerich, Sandia National Laboratories, Albuquerque, NM 87185-0781

Funding — Year Initiated: FY96 — Expected completion date: FY97

Total prior to FY96: ____ — Authorized in FY96: $40,000

Total expended in FY96: $40,000 (Estimated) — Requested for FY97, if any: $40,000

In-house: $20,000

Contracts (identify): $20,000 [Sandia National Laboratories, Purchase Order No. A49107D(SLS)]

Grants (identify):

Status of study: ☐ Completed in FY96 ☒ Continued in FY97

If continued in FY97: ☐ with funds remaining? ☒ with FY97 funds?

If transitioned to other funding, to RTOP (number?): ____

to Program (name?): ____ to Other (identify): ____

Purpose of investigation

To investigate the capability of laser scanning confocal microscopy (LSCM) to provide *quantitative* information about the porous microstructure of various thermal protection system (TPS) materials. The idea is to use LSCM to obtain digitally stored representations of the pore structure and to devise computational algorithms to extract numerical values for such quantities as porosity, surface area per volume, pore size and orientation distributions, etc. This information will then be incorporated into various modeling efforts, such as, e.g., internal radiation transport and gas flow in fibrous insulations.

FY96 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

This work is still in progress, but future publication and presentation of the results of this investigation are anticipated.

Planned future work

Plans include optimizing the LSCM process, obtaining more data on more TPS material, writing computer codes for extracting desired quantities from LSCM data, and inputting derived information into various computational models of material properties and behavior.

Prepared by: Jochen Marschall — Org. Code: STM — M/S: 234-1 — Phone: (415) 604-0829

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1996

Title of Investigation: A Limited Pressure Cycle Engine for High Specific Output

Investigator(s) (show affiliation): Mark D. Moore and Andrew S. Hahn, Ames Research Center, Moffett Field, CA 94035-1000

Funding — Year Initiated: FY96 — Expected completion date: FY97

Total prior to FY96: _____ — Authorized in FY96: $34,000

Total expended in FY96: $34,000 (Estimated) — Requested for FY97, if any: $20,000

- In-house
- Contracts (identify)
- Grants (identify)

Status of study: ☐ Completed in FY96 ☒ Continued in FY97

If continued in FY97: ☐ with funds remaining? ☒ with FY97 funds?

If transitioned to other funding, to RTOP (number?): 537-10-01

to Program (name?): ERAST — to Other (identify): _____

Purpose of investigation

To experiment on an engine cycle designed to meet the needs of NASA's high-altitude aircraft program by providing a significantly higher power output per pound of engine weight without decreasing the engine life through higher loads or piston speeds. Tests will include measurements to determine the pressures, temperatures, work ratios, specific fuel consumption, timing adjustments, combustion knock and emissions, and water injection rates that yield optimal power results.

FY96 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

None yet.

Planned future work

During the next fiscal year, a contract to perform the experimentation will be awarded. A test engine will be constructed and then run with multiple sensors for determination of key data. The hardware will be inspected for damage and wear, and a report will be written explaining the test results.

Prepared by: Mark Moore — Org. Code: APS — M/S: 237-11 — Phone: (415) 604-0968

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1996

Title of Investigation: Ultra-Light Entry Systems

Investigator(s) (show affiliation): Marcus S. Murbach and Demetrius Kourtides, Ames Research Center, Moffett Field, CA 94035-1000

Funding — Year Initiated: FY95 — Expected completion date: FY97

Total prior to FY96: $40,000 — Authorized in FY96: $40,000

Total expended in FY96: (Estimated) — Requested for FY97, if any:

- In-house: $40,000
- Contracts (identify):
- Grants (identify):

Status of study: ☐ Completed in FY96 ☒ Continued in FY97

If continued in FY97: ☒ with funds remaining? ☐ with FY97 funds?

If transitioned to other funding, to RTOP (number?):

to Program (name?): to Other (identify):

Purpose of investigation

To develop a very low ballistic coefficient, or "ultra-light," atmospheric entry system applicable to certain classes of planetary exploration missions. Reducing the ballistic coefficient (particularly below 10 kg/m^2) resulted in deceleration at a much higher altitude, where the lower density contributes to a significant reduction in the convective heat transfer rate. This reduction allows for the use of high-temperature ceramic materials (both rigid and flexible) in place of the heavier ablative heat shields in common use. Numerous probe design advantages resulted.

FY96 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

Murbach, Marcus S.; Kourtides, Demetrius; and Chen, Y. K.: Ultra-Light Entry Systems for Planetary Missions. AIAA-96-0616, presented at 34th Aerospace Sciences Meeting and Exhibit, Reno, Nev., Jan. 8–11, 1996.

Murbach, Marcus S.; Kourtides, Demetrius; and Chen, Y. K.: Ultra-Light and Ultra-Precise Mars Missions. Submitted to AIAA 35th Aerospace Sciences Meeting and Exhibit, 1997.

Planned future work

During the next fiscal year, arc-jet testing of one of the prototypes will be completed. In addition, two sounding rocket flights launched from the White Sands Test Facility will be used to further mature and validate the general concept. The first flight will verify the data-acquisition system and electrical/mechanical interfaces (a "piggyback"); the second will be used to fly numerous probes through a trajectory with Mach numbers as high as 8 (a "dedicated" launch). In addition, further work regarding the penetrator will be performed.

Prepared by: Marcus S. Murbach — Org. Code: SFS — M/S: 244-14 — Phone: (415) 604-3155

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1996

Title of Investigation: Analysis of Molecular S_2 Spectra Observed during Impact of Comet Shoemaker-Levy 9 with Jupiter

Investigator(s) (show affiliation):
Harry Partridge, Ames Research Center, Moffett Field, CA 94035-1000;
Atul D. Pradhan, National Research Council, Ames Research Center;
David Schwenke, Ames Research Center;
Ken Dyall, Eloret Institute, Sunnyvale, CA 94087

Funding — Year Initiated: FY96 — Expected completion date: FY97

Total prior to FY96: ____ — Authorized in FY96: $40,000

Total expended in FY96: (Estimated) — Requested for FY97, if any: ____

- In-house: $40,000
- Contracts (identify)
- Grants (identify)

Status of study: ☐ Completed in FY96 ☒ Continued in FY97

If continued in FY97: ☒ with funds remaining? ☐ with FY97 funds?

If transitioned to other funding, to RTOP (number?): ____

to Program (name?): ____ to Other (identify): ____

Purpose of investigation

To determine accurate synthetic spectra of the X-B transition in the S_2 molecule in order to analyze spectra taken of the Shoemaker-Levy 9 comet impact with Jupiter.

FY96 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

Pradhan, Atul; and Partridge, Harry: Theoretical Study of the B-X and B″-X Band Systems of S_2. Chem. Phys. Letters, vol. 255, 1996, pp. 163–170.

Planned future work

To finish work on spectroscopy and publish second paper.

Prepared by: Harry Partridge — Org. Code: STC — M/S: 230-3 — Phone: (415) 604-5236

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1996

Title of Investigation: Does Ultraviolet Radiation Affect Carbon Isotope Fractionation?

Investigator(s) (show affiliation): Lynn Rothschild, David Peterson, and David DesMarais, Ames Research Center, Moffett Field, CA 94035-1000

Funding — Year Initiated: FY96 — Expected completion date: _____

Total prior to FY96: _____ — Authorized in FY96: $40,000

Total expended in FY96: $40,000 (Estimated) — Requested for FY97, if any: $40,000

- In-house: $40,000
- Contracts (identify):
- Grants (identify):

Status of study: ☐ Completed in FY96 ☒ Continued in FY97

If continued in FY97: ☐ with funds remaining? ☒ with FY97 funds?

If transitioned to other funding, to RTOP (number?): _____

to Program (name?): _____ to Other (identify): _____

Purpose of investigation

To determine if ultraviolet (UV) radiation affects stable carbon isotope ratios. If so, is there an ecologic (e.g., microbial mat vs. phytoplankton) or taxonomic (e.g., prokaryote vs. eukaryote, alga vs. plant) correlation with the effect?

FY96 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

None so far.

Planned future work

To grow organisms outside in the presence and absence of UV and to analyze biomass for $\Delta\delta^{13}C_{org}$ values to determine if there is a difference between treatments.

Prepared by: Lynn Rothschild — Org. Code: SGE — M/S: 239-12 — Phone: (415) 604-6525

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1996

Title of Investigation: Computation of the Low-Temperature Rate Constants for the Reaction $HO_2 + O_3 \rightarrow OH + O_2 + O_2$

Investigator(s) (show affiliation): David W. Schwenke, Ames Research Center, Moffett Field, CA 94035-1000;
Stephen P. Walch, Eloret Institute, Sunnyvale, CA 94087

Funding — Year Initiated: FY95 — Expected completion date: FY97

Total prior to FY96: $40,000 (FY95 funds) — Authorized in FY96: $40,000

Total expended in FY96: $40,000 (Estimated) — Requested for FY97, if any:

- In-house
- Contracts (identify): $40,000 (NAS2-14031)
- Grants (identify):

Status of study: ☐ Completed in FY96 ☒ Continued in FY97

If continued in FY97: ☒ with funds remaining? ☐ with FY97 funds?

If transitioned to other funding, to RTOP (number?):

to Program (name?): to Other (identify):

Purpose of investigation

The HO/HO_2 catalytic cycle for ozone depletion involves the reactions:

$HO + O_3 \rightarrow HO_2 + O_2$

$HO_2 + O_3 \rightarrow HO + O_2 + O_2$

The net reaction is $2\ O_3 \rightarrow 3\ O_2$.

The rate constant for the $HO_3 + O_2$ reaction is uncertain in the low-temperature region, and the purpose of these studies is to compute the required rate constant information.

FY96 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

Walch, Stephen P.: On the HO/HO_2 Catalytic Cycle for Ozone Depletion; I. Computed Potential Energy Surfaces for $HO + O_3$ and $HO_2 + O_3$. J. Chem. Phys., in preparation.

Planned future work

Work will continue on the abstraction pathway. After this work is completed, a coordinated effort will be carried out to develop a potential energy surface for use in the quantum scattering calculations, which will determine the low-temperature rate constant.

Prepared by: S. P. Walch — Org. Code: STC — M/S: 230-3 — Phone: (415) 604-6189

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1996

Title of Investigation: Adaptation of Bone to Mechanical Stimulation: Development and Characterization of a Unique Osteoblast Loading System

Investigator(s) (show affiliation): Nancy Searby and Emily Morey-Holton, Ames Research Center, Moffett Field, CA 94035-1000;
Ruth Globus, University of California, San Francisco, San Francisco, CA 94143;
Ekhson Holmuhamedov, National Research Council, Ames Research Center

Funding — Year Initiated: FY96 — Expected completion date: FY98

Total prior to FY96: — Authorized in FY96: $40,000

Total expended in FY96: $40,000 (Estimated) — Requested for FY97, if any: $40,000

In-house: $8500: Engineering support and hardware

Contracts (identify):

Grants (identify): $31,500 NCC 2-589 Gravity and Skeletal Growth: Technician support and lab supplies

Status of study: ☐ Completed in FY96 ☒ Continued in FY97

If continued in FY97: ☐ with funds remaining? ☒ with FY97 funds?

If transitioned to other funding, to RTOP (number?):

to Program (name?): to Other (identify):

Purpose of investigation

To determine the role of the osteoblast's cytoskeleton and attachments to the extracellular matrix in responding to mechanical loads. To accomplish this, a system will be developed to apply mechanical loads to osteoblasts. Determination of the mechanisms that osteoblasts, or bone forming cells, use to respond to mechanical loading will lead to a better understanding of the role osteoblasts play in situ in bone as they adapt bone structure in response to daily mechanical loads generated by physical activities such as walking, or reduced activity as seen in spaceflight.

FY96 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

Planned future work

The cell loading system development will be completed in 1997, and science testing will be initiated to determine the osteoblast response to mechanical loading. As the responses of the osteoblast cytoskeleton and its extracellular matrix attachments are characterized, a model based on structural analysis of the cell and the surrounding structure will be developed.

Prepared by: Nancy Searby Org. Code: SLR M/S: 236-5 Phone: (415) 604-6794

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1996

Title of Investigation: A New Method to Test Rotor Hover Performance

Investigator(s) (show affiliation): Mark J. Silva and Frank Caradonna, Aeroflightdynamics Directorate, U.S. Army Aviation and Troop Command, Ames Research Center, Moffett Field, CA 94035-1000

Funding — Year Initiated: FY95 — Expected completion date: FY97

Total prior to FY96: $40,000 — Authorized in FY96: $40,000

Total expended in FY96: $40,000 (Estimated) — Requested for FY97, if any: $40,000

- In-house
- Contracts (identify)
- Grants (identify)

Status of study: ☐ Completed in FY96 ☒ Continued in FY97

If continued in FY97: ☒ with funds remaining? ☐ with FY97 funds?

If transitioned to other funding, to RTOP (number?) _____

to Program (name?) _____ to Other (identify) _____

Purpose of investigation

To develop a new concept for rotor hover performance testing that eliminates flow unsteadiness and permits the acquisition of highly reliable data that will permit accurate evaluation of rotor designs and the validation of new computational fluid dynamics (CFD) codes.

FY96 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

A paper will be presented at the American Helicopter Society Aeromechanics Specialists Meeting in 1997.

Planned future work

To scale the method to permit the testing of larger rotors and provide the means to do such testing.

Prepared by: Frank Caradonna — Org. Code: YF — M/S: 215-1 — Phone: (415) 604-5902

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1996

Title of Investigation: Use of Evolving Microbial Systems as a Domain for Development of Autonomous Artificial Intelligence Software

Investigator(s) (show affiliation): David Thompson , Ames Research Center, Moffett Field, CA 94035-1000;
R. Levinson and P. Robinson, Caelum-Recom Technologies, Ames Research Center;
R. Mancinelli, D. Smernoff, and M. White, SETI Institute, Ames Research Center

Funding — Year Initiated: FY95 — Expected completion date: FY98

Total prior to FY96: $40,000 — Authorized in FY96: $40,000

Total expended in FY96: (Estimated) — Requested for FY97, if any: $40,000

- In-house: $40,000
- Contracts (identify)
- Grants (identify)

Status of study: ☐ Completed in FY96 ☒ Continued in FY97

If continued in FY97: ☐ with funds remaining? ☒ with FY97 funds?

If transitioned to other funding, to RTOP (number?) _____

to Program (name?) _____ to Other (identify) _____

Purpose of investigation

To achieve advances in artificial intelligence (AI)-based software technology for control, diagnosis, and repair of complex microbial experimental systems, and to gain a better understanding of the role that nitrogen fixing and denitrifying microbial systems play in nutrient cycling, atmospheric evolution, and biogeochemical (BGC) cycles on Earth. The goal is advocation of application of the autonomous control software within NASA (e.g., advanced life support, office space science, autonomous spacecraft).

FY96 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

The growth of *Pseudomonas fluorescens*, a denitrifyer, was monitored and controlled in the bioreactor system under varying oxygen levels from 0 to 100 percent. Traditional control software was designed and implemented (i.e., LabView). AI software elements were then fully integrated with the traditional control via a severable communication link, which operates either on the same platform or via a Web interface. Quantitative and qualitative thermal models were developed and integrated into the AI software architecture.

Smernoff, D. T.; and Mancinelli, R. L.: Terrestrial and Space-Based Applications of Autonomous Instrumentation. Adv. Space Res., 1997 (in press).
Mancinelli, R. L.; Smernoff, D. T.; and White, M. R.: Controlling Denitrification in Closed Artificial Ecosystems. Adv. Space Res., 1997 (in press).
Robinson, P.; Autonomous Design and Execution of Process Controllers for Untended Scientific Instruments. 1st International Conference on Autonomous Agents, Marina del Rey, Calif., Feb. 5–8, 1997.

Planned future work

- Integrate models of microbial growth and competition into existing software.
- Test the validity of a model of the evolution of the N-cycle (Mancinelli and McKay, Orig. of Life, Evol. Bios., vol. 18, 1988, p. 311).
- Refine development of the AI architecture based on results of the microbe tests to achieve increasing levels of autonomy.

Prepared by: David Thompson/ Rocco Mancinelli — Org. Code: IC/SSX — M/S: 269-2/ 239-12 — Phone: (415) 604-4759/6165

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1996

Title of Investigation: Chaos in Interstellar Chemistry

Investigator(s) (show affiliation): A. G. G. M. Tielens, Ames Research Center, Moffett Field, CA 94035-1000

Funding — Year Initiated: FY96 — Expected completion date: FY97

Total prior to FY96: ____ — Authorized in FY96: $30,000

Total expended in FY96: (Estimated) — Requested for FY97, if any: $30,000

- In-house: $5000
- Contracts (identify):
- Grants (identify): $25,000 (NCC2-548)

Status of study: ☐ Completed in FY96 ☒ Continued in FY97

If continued in FY97: ☐ with funds remaining? ☒ with FY97 funds?

If transitioned to other funding, to RTOP (number?): ____

to Program (name?): ____ to Other (identify): ____

Purpose of investigation

To develop a theoretical model for interstellar chemistry, with the aim of determining the factors that control the onset of chaotic behavior. The results will be used to determine the influence of chaos on the formation of stars and planetary systems through its influence on the degree of ionization and on the abundance of cooling species.

FY96 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

A numerical code that calculates the chemical abundances in interstellar clouds has been developed. Initially, this code contained approximately 4000 reactions between approximately 500 astronomically relevant species, but a trimmed-down version of 170 reactions between 40 species still retains the essential characteristics of the complete chemical network and reproduces the calculations of the full code well. Using this code, a systematic study of the (external) parameter space (cosmic ray ionization, FUV photodissociation and photoionization, temperature, density, elemental abundances) has begun.

Planned future work

Systematic study of the parameter space will continue. An analytical analysis of the chemical network will be performed. To that end, the number of species will be reduced even further, using lumping techniques. In this way, the number of equations involved will be limited to perhaps five. Thus the important control parameters for the onset of chaos can be identified analytically. The results of this analytical approach will then be validated against the full code.

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NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1996

Title of Investigation: Modeling High Energy Aerocapture Trajectories for Outer Planet Orbiter Missions

Investigator(s) (show affiliation): Paul Wercinski, Ames Research Center, Moffett Field, CA 94035-1000; Periklis Papadopolous and Ethiraj Venkatapathy, Thermosciences Institute, Palo Alto, CA 94303; Lily Yang, Sterling Software Systems, Ames Research Center

Funding — Year Initiated: FY96 — Expected completion date: FY98

Total prior to FY96: ____ — Authorized in FY96: $40,000

Total expended in FY96: $40,000 (Estimated) — Requested for FY97, if any: $40,000

In-house

Contracts (identify): $40,000 (Thermosciences Institute, Sterling Software)

Grants (identify)

Status of study: ☐ Completed in FY96 ☒ Continued in FY97

If continued in FY97: ☐ with funds remaining? ☒ with FY97 funds?

If transitioned to other funding, to RTOP (number?): ____

to Program (name?): ____ to Other (identify): ____

Purpose of investigation

First, to characterize the static aerodynamic coefficients of the axisymmetric biconic shape in realistic flow conditions representative of actual flight trajectory, including the lift and drag coefficients of the entry vehicle at various angles of attack; second, to calculate the heating distribution over the surface of the entry vehicle at various trajectory points; and finally, to determine thermal protection system (TPS) requirements from the coupled heating distributions at several trajectory points. With this analysis, an attempt to incorporate approximate methods of estimating the heating distribution (and subsequent thermal protection material requirements) with an actual trajectory simulation will be assessed and performed if appropriate.

FY96 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

None at this time.

Planned future work

Work will focus on further refining heating estimates with TPS sizing estimates.

Prepared by: Paul Wercinski — Org. Code: STA — M/S: 229-3 — Phone: (415) 604-3157

NASA
Ames Research Center

Director's Discretionary Fund Report

Fiscal Year 1996

Title of Investigation: Fastenerless Structural Connections for Tiltrotor Aircraft

Investigator(s) (show affiliation): John Zuk, Ames Research Center, Moffett Field, CA 94035-1000; Clem Hiel, SVERDRUP, Ames Research Center

Funding — Year Initiated: FY96 — Expected completion date: FY97

Total prior to FY96: ____ — Authorized in FY96: $40,000

Total expended in FY96: (Estimated) — Requested for FY97, if any: $40,000

- In-house: $40,000
- Contracts (identify)
- Grants (identify)

Status of study: ☐ Completed in FY96 ☒ Continued in FY97

If continued in FY97: ☐ with funds remaining? ☒ with FY97 funds?

If transitioned to other funding, to RTOP (number?): ____

to Program (name?): ____ to Other (identify): ____

Purpose of investigation

To conduct innovative research leading to the development of a new class of fastenerless connections, called "snap joints," for assembly of composite structures, with special emphasis on tiltrotor aircraft.

FY96 applications of results, patents, reports/publications, papers at meetings, any awards received, etc.

(1) Formulated snap joint ideas, developed conceptual designs utilizing computer-aided design (CAD), fabricated and evaluated candidate test specimens.
(2) Fabricated a full-scale generic snap joint illustrating ease of assembly and positive interlocking features.

Planned future work

(1) Expand concept to three universal snap joint configurations.
(2) Conduct finite element analyses.
(3) Fabricate, conduct test measurements, and perform concept application demonstrations.
(4) File patent application.
(5) Establish an industrial partnership.

Prepared by: John Zuk — Org. Code: APT — M/S: 237-11 — Phone: (415) 604-6568

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13. ABSTRACT ***(Maximum 200 words)***

This technical memorandum contains brief technical papers describing research and technology development programs sponsored by the Ames Research Center Director's Discretionary Fund during fiscal year 1996 (October 1995 through September 1996). An appendix provides administrative information for each of the sponsored research programs.

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